THE PRODUCTION OF FIELD CROPS

A TEXTBOOK OF AGRONOMY

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THE PRODUCTION OF FIELD CROPS

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PREFACE TO THE THIRD EDITION

The Second World War interrupted the authors' avowed purpose of revising this text. However, research in agronomic lines was greatly reduced during the war, and, too, classes in farm crops practically came to a standstill.

Many changes in the development of the crops industry have taken place since the last revision of this book. Crop yields are steadily rising; farming has been more thoroughly mechanized; much of the drudgery of farm work has been eliminated; and in many cases profits have increased.

In revising this text, an effort has been made to revise or omit old material and add new material. In fact, many chapters have been almost completely rewritten.

The authors have been highly gratified at the very fine reception accorded their text. It is for this reason that they are particularly hopeful that this third edition will prove even more valuable than the preceding editions as a source of information concerning farm crops.

THE AUTHORS

BLACKSBURG, VA.
July, 1948

PREFACE TO THE FIRST EDITION

This book is designed to meet the needs of a standard course in field crops. In its preparation the outline for a standard introductory course in field crops recently adopted by the American Society of Agronomy was followed as closely as practicable. This outline was prepared by a committee of the Society, composed of Dr. W. C. Etheridge of Missouri and Prof. M. L. Fisher of Indiana.

It is thought that a knowledge of the fundamentals underlying the production of all crops is desirable before individual crops are treated. For this reason the first part of the book is devoted to a discussion of such fundamentals. In the production of many crops there are also numerous common practices, such as seedbed preparation, seeding methods, the use of fertilizers, and so forth. Such practices are discussed separately with the hope that the student may apply them in their proper place and thus avoid the necessity of repeating a study of these practices under the several crops.

In the discussion of individual crops, no attempt has been made to exhaust each subject nor has the value of any crop been greatly emphasized on account of its relative importance in the country as a whole. It is realized that a crop may be of great local importance and of little national importance.

In short, the aim has been to prepare a text with a wide field of usefulness rather than one with a field limited to certain areas. It is expected that the instructor who may use the text will supplement the information contained therein with data directly applicable to his local conditions.

For valuable assistance given, grateful acknowledgment is made to Dean H. L. Price, who read the chapter on plant improvement; to Dr. F. D. Fromme, who read the subject matter on crop diseases; and to Prof. W. J. Schoene, who read the subject matter on crop insects. The authors also take this opportunity to thank Prof. Lyman Carrier, who revised the chapter on the beginnings of plant culture; Prof. A. B. Massey, who reviewed much of the subject matter pertaining to botany; and Prof. James Duff, who very painstakingly read the entire manuscript.

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SECTION I

GENERAL

CHAPTER I

BEGINNINGS OF PLANT CULTURE

Plant culture began a great many years ago; where and when the beginning took place no one can say. Tribes of primitive peoples in comparatively modern times have cultivated plants and then disappeared without leaving more than a trace of their industry. It is open to conjecture how many such tribes there were prior to the civilizations that have left records of their existence. The earliest peoples of whom we have definite knowledge had made great strides as agriculturists. Perhaps there was a time when the most highly developed races of human beings were no further advanced than are the most primitive savages to be found at the present time. If such was the case, it is easy to imagine the gradual development of agricultural practices over a very, very long period of time. Thousands, probably hundreds of thousands, of years have elapsed since man first appeared on the earth. His greatest material accomplishments during that long period have been the domestication of plants and of animals.

Antiquity of American Agriculture. American agriculture is generally supposed to be not so old as that of Egypt and Asia. The evidence bearing on the subject is negative.

No human remains that bear anything like the antiquity of those discovered in the Old World have been found in America. Modern research is bringing to light, however, evidence to prove that human activity in America is far more ancient than is generally supposed. The finding of a fossil ear of maize by F. H. Knowlton in 1914 indicates the long period of time that has elapsed since that plant was first brought under cultivation. Anthropologists may at any time make discoveries that will change our whole conception of the birthplace of mankind. We have little knowledge of the migrations of the early races but we know that these migrations may have been quite extensive, especially those following the glacial periods. There are evidences that some regions now arid were once productive and were cultivated by man. Conse-

quently, in a discussion of the origin of our cultivated crops, all that can be done now is to show where they were in use and when their earliest evidence appears in history.

Cultivation a Necessity. At first men lived upon food secured from wild plants and from hunting and fishing. Grim necessity rather than love of plants caused primitive man to domesticate plants. When the supply of food furnished by wild plants and game became insufficient, attention was then turned to agriculture.

Man first cultivated those plants common to his surroundings, as there was but little opportunity for introductions from any considerable distance. The plants chosen were those which were most productive and easiest to grow. Such crops as wheat, maize, sweet potatoes, several millets of the genus *Panicum*, tobacco, and other plants, especially the annuals, were early grown. It is found that, as time progressed and peoples migrated, plants were introduced from one region into another and that the less desirable plants of one locality were largely replaced by the more valuable ones of other regions.

Antiquity of Cultivation. The exact time that cultivation started is difficult to state. It must have started at least 10,000 to 12,000 years ago. The people of that period cultivated and ate wheat, barley, and millet. Apparently, oats and rye were not known in the Mediterranean region at least. In the pyramid of Gizeh in Egypt, according to DeCandolle,[1] was found a drawing representing figs. This pyramid is supposed to have been built about 2900 B.C. In China, the Emperor in 2700 B.C. began the ceremony of sowing five kinds of useful plants every year. The plants used were rice, yams, wheat, and two kinds of millet. It is logical to suppose that these plants were under cultivation before that time. It is probable that agriculture is as old in China as in Egypt and that it started about the same time in the valleys of the Euphrates and the Nile.

The ancient Egyptians and the Phoenicians grew plants along the Mediterranean, and the Aryan nations in their migrations toward Europe about 2500 to 2000 B.C. carried with them plants cultivated in Asia. Plants were, however, probably cultivated in Europe before the Aryan migrations, but the relics of the ancient Danes, 10,000 B.C. or earlier, do not give evidence of cultivated plants. On the other hand, the lake dwellers of Switzerland, 5000 to 4000 B.C., apparently cultivated a few plants. The evidence from the very earliest times shows they had flax, barley, wheat, millet, and peas. Oats and a dwarf field bean were added during the Bronze Age.

Regions of Origin. DeCandolle[1] studied the history of 247 species of cultivated plants. Of these he considered 199 originated in the Old

World and 45 in America, but as to the origin of the other 3 species he was uncertain. It is probable that the domestication of some plants was carried on independently in different places. Many species appeared at the same time in the Mediterranean basin and western Asia, in India and the Asiatic Archipelago, in the West Indies, Mexico, and Colombia, and in Peru and Brazil. In some regions there are apparently no native cultivated plants, as in the Arctic and Antarctic regions.

The area covered by the United States has given only a very few nutritious plants worthy of cultivation. Of these may be mentioned the Jerusalem artichoke, the sunflower, the squash, and the pumpkin. There were numerous other edible plants that were not cultivated by the Indians. Maize, which was probably introduced from Central or South America, is the most important New World plant.

Patagonia and the Cape have not furnished any of our cultivated plants. Australia and New Zealand have furnished a tree, *Eucalyptus globulus*, and a vegetable, *Tetragonia*. Their floras furnish no grasses corresponding to the cereals, no leguminous plants with edible seeds, and no Cruciferae cultivated for their fleshy roots. The original distribution of cultivated species was apparently very unequal. It had no relation to the needs of man or to the extent of territory.

The advance made by agriculture in ancient times was due to certain more or less well-defined reasons. This statement still holds true in modern times. It was found in the early periods that certain sections were peopled with husbandmen who cultivated plants and had domesticated animals. In other regions agriculture was not so far advanced. It is probable that some peoples appreciated more highly the value of cultivated plants, that the climatic conditions of some regions were more favorable, and again that distance was a handicap to the spread of valuable species.

It was probably due to the favorable climate that rice and several leguminous plants were cultivated at an early period in southern Asia; barley and wheat in Mesopotamia and Egypt; the *Panicums* in Africa; and maize, the potato, and the sweet potato in America. Since the climate was unfavorable in the north of Asia, Europe, and America, agriculture probably began in these regions late, but the abundant hunting and fishing obtaining there compensated to a great degree. In Australia, Patagonia, and the south of Africa, the native plants were very poor, and distance prevented the spread of more desirable species.

Vavilov[2] states that the chief cultivated plants originated in the mountains and not in the river valleys as is frequently claimed. The five mountainous regions of origin are as follows:

Southwestern Asia, including India, southern Afghanistan, and the adjacent regions of mountainous Bokhara, Kashmir, Persia, Asia Minor, and Transcaucasia. Here originated soft and club wheats, rye, small-seeded flax, small-grained peas, lentils, horse beans, vetchling, chick pea, many vegetables, Asiatic cotton (*Gossypium herbaceum* L., *G. arboreum* L.), etc.

Southeastern Asia, including mountainous China, Japan, Nepal, and the adjoining regions. Here originated naked oats, hull-less barley, millet, soybeans, many Cruciferae, and many endemic species of fruit trees.

The Mediterranean center embracing northern Africa (Egypt, Algeria, Tunis), Palestine, and Syria, Greece with its islands, Spain, Italy, and partly the western and southwestern regions of Asia Minor. Here originated a number of cultivated plants, such as durum wheat, oats (*Avena byzantine*), large-seeded flax, large-grained peas, vetchling, horse beans, lentils, beet root, and many vegetables and fruit trees.

In northern Africa, Abyssinia and its adjacent mountain regions constitute an independent center. Here many cultivated plants originated, such as hulled barley, violet-grained wheat, peas, races of oats, and many other plants.

In western America, Mexico, and Peru, with the adjoining mountainous countries, were the seats of primeval agriculture and the center of origin of plants. Here originated potatoes, Jerusalem artichoke, corn, beans, tobacco, sunflower, American cotton, fruit trees, and many other plants.

Existence of Wild Forms. Of the 247 species studied by DeCandolle,[1] 193 are said to be known in the wild state; 27 are doubtful, as half wild; and 27 have not been found in the wild form. In order that a species may exist for a great length of time in the wild state, it must be able to grow and to propagate its kind under adverse conditions.

Some of the species of which the wild form is not known are the chick pea (*Cicer arietinum*), lentil (*Ervum lens*), tobacco (*Nicotiana tabacum*), wheat (*Triticum vulgare*), and maize (*Zea mays*).

These species, with the exception of tobacco, have seeds that are food for animals, birds, and insects, and the seeds do not usually pass through the alimentary canal entire. This is probably the main reason for their nonexistence in the native form. Also the storage conditions have to be rather favorable if the power to grow is retained.

It is an interesting fact that all the bread plants of importance and all the economic species of annuals have been domesticated by what we term savage or uncivilized peoples. Since the historical records of civilized man began, there have been a few species of forage crops, mostly grasses, some fruits, and ornamentals, which have been brought under cultivation. But during the past 4,000 years there has not been discovered and culti-

vated a single species of plant that surpasses in value the cereals, sweet potatoes, beans, millets, bananas, and sorghums.

The domestication of the American strawberry is one of the most notable instances of modern times where the art of man has improved on the natural wild product.

Spread of Cultivated Forms. In the early periods there was apparently no wide dissemination of cultivated species. Natural barriers, such as bodies of water, mountains, forests, and deserts, kept the agriculturally inclined races restricted to definite regions, and communication with other races at a distance was unusual. It was only when whole races migrated from one region to another that there was much transporting of cultivated species. The line of demarcation between species of the Old World and the New is much more clearly defined than that between Europe and Asia or Asia and Africa. If the Northmen discovered America in pre-Columbian times, as is quite generally supposed, they apparently did not introduce any cultivated species either from Europe to America or from America to Europe. But after the voyage of Columbus and the circumnavigation of the world, there was a very rapid dispersion of cultivated forms from one hemisphere to the other. Maize, sweet potatoes, cassava, and tobacco entered into the agriculture of Africa and Asia at very early dates; and ginger, cinnamon, sugar cane, citrus fruits, and other Old World plants were taken to America by the Spaniards soon after the discovery.

In a number of instances species of plants were not cultivated until they had been taken to countries other than their native countries. The Australian eucalyptus was first cultivated in Algeria and the cinchonas of America in the south of Asia. Many of the varieties of the domesticated strawberry trace back to European origin. The evidence indicates that the wild American strawberry was taken to Europe and there grown and improved by crossing and selection. These improved varieties were later brought to America.

The cultivation of new species remained almost stationary during the three centuries preceding and the two or three centuries following the voyages of Vasco da Gama and of Columbus. It was not until the middle of the nineteenth century that new cultivations of much utilitarian value were made. There was, however, during this period a rapid diffusion of cultivated plants already in cultivation.

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Topics for Discussion

1. What important crop plants has the part of North America covered by the United States contributed to agriculture?

2. What important crop plants has the continent of North America contributed?

3. What section of the world has contributed most economic plants to agriculture?

4. What are the United States' most important contributions to the knowledge of crop production?

CHAPTER II

ECONOMICS OF CROP PRODUCTION

Profits from farm crops depend upon two factors offering wide fields of enterprise: economic production, and efficient marketing. Since it is not likely that any system of marketing, however effective, will allow a profit to be made from crops which have been produced at a very high cost, the problem of economic production must precede marketing considerations.

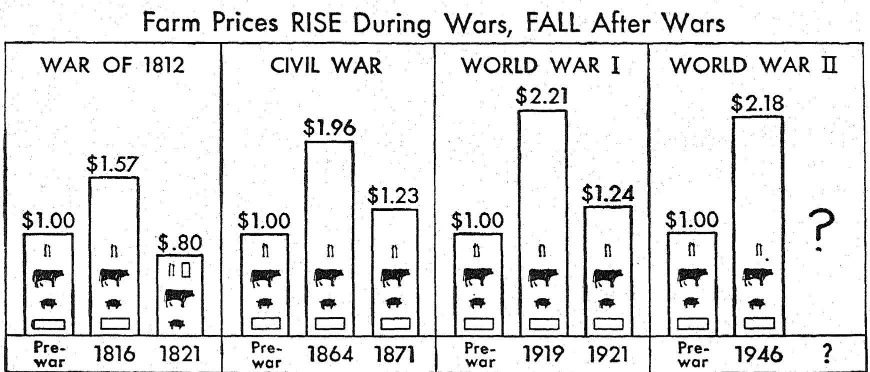

FIG. 1. Farm prices before, during, and after wars.

According to Bartlett,[1] farm prices rise during wars and fall after wars. He makes the following comparisons:

War of 1812. Prices of farm products were highest in 1816, 2 years after the war ended. By 1821, 5 years later, prices had fallen to about half those received in 1816.

Civil War. Prices of farm products in 1864 were nearly double those received before the war. By 1871, 7 years later, prices had fallen to about five-eighths of those received in 1864.

First World War. Prices of farm products in 1919 were about 2¼ times those received before the war. By 1921, 2 years later, prices had fallen to about three-fifths of those received in 1919.

Second World War. Prices of farm products in 1946, like those of 1919, were about 2¼ times those received before the war. If history repeats itself, prices of farm products will fall in the next few years.

These facts are graphically shown in Fig. 1.

The universal economic upheaval that followed the First World War greatly changed conditions in this country in so far as they affect crop production. For at least two decades prior to 1930, economic necessity seemed to demand that agricultural production be increased as rapidly as practicable in order to meet the demands of a rapidly increasing population and an expanding export trade. With the coming of the depression of the thirties the country was suddenly confronted with exactly the reverse condition. Owing to a falling off of export trade, reduced consumption by a financially distressed buying public, an increased farming population, and greater production due to the use of more efficient farm machinery, most farm products were produced in quantities that far exceeded the demand for them. More farm products were produced than could be sold at a profit, on the average, by the farmer. Among the many suggestions for the relief of this condition, that of controlled production received perhaps the most widespread approval of farmers. Controlled production was simply an attempt on the part of the government to induce farmers to reduce the acres planted and the animals kept to a point where the potential supply of products would not exceed the prospective demand as forecast by carefully compiled statistical evidence.

With the Second World War, as usual with wars, came a greatly increased demand and higher prices for farm products. Surpluses began to disappear, and production goals were set, and government subsidies were paid to encourage farmers to produce more and more. Effort on the part of the farmers, the use of better seed and varieties of crops, more liberal applications of commercial fertilizer, and unusually favorable weather resulted in an all-time record production of crops and livestock during the 7-year period 1940–1946. The production of food nutrients by farmers during this period was well above that of the 1935–1939 average.

With the ending of hostilities the demand for food increased, because of the necessity for the United States to feed the war-torn and devastated countries. Higher prices and government price supports encouraged farmers to meet the demand.

Thus efforts to restrict production were followed by efforts to expand it, because of changed conditions. Throughout time this has been happening. No longer than twenty-five years after the settlement at Jamestown, restrictions were placed on tobacco culture because of universally low prices. In time the restrictions were lifted. What has happened in the past is very likely to be repeated frequently in the future. It may be said, however, that regardless of changing demands, the principal practices of crop production will remain essentially the same.

Relative Importance of Crops and Other Farm Products. The relative importance of crops to other farm products varies with the region. According to agricultural statistics published by the U.S. Department of Agriculture for 1946, of every dollar received in 1945 by farmers, 56 cents was derived from livestock and livestock products, and 44 cents was received from farm crops. However, the character of farm sales varies greatly in different sections of the country. In the cotton states it is to be expected that crops will predominate in value. Thus, for every dollar's worth of products sold in Georgia, 70 cents is derived from crops and 30 cents from livestock and livestock products. In Iowa, on the other hand, for every dollar's worth of products sold, the farmer receives 83 cents from livestock and livestock products and 17 cents from crops.

In 1945 the amount received by farmers for crops in the United States was $9,055,528,000 and that for livestock and livestock products, $11,725,355,000. Farmers sometimes find it more profitable to market crops through livestock than to market them as crops. They have marked ability to sense economic trends and conditions, and they are quick to change from a situation of unfavorable relationships to one of more favorable. If they can make more money feeding corn to hogs, they usually do so. If they can make more money by selling corn on the market, they are likely to dispose of it in that manner.

Briefly, it may be said that crops are significant in that they have a high value per se, are important in domestic and foreign trade, and are essential to the existence of the animal industry.

Factors of Crop Production. The amount of the different crops produced depends upon many factors. Some of these factors are under control of the farmer, whereas others are not. Some of the factors that are more or less under the control of the grower are choice of good seed of the best varieties, selection of suitable land, judicious fertilizing, proper systems of cropping, and wise cultivation. The factors often not controllable are weather, pests, diseases, etc. It may be readily seen that the amount of crops produced may be determined by factors beyond the control of the farmer. Likewise, the grower may exercise considerable influence on the yields of crops.

Influence of Crop Yields on Community Prosperity. The general prosperity and progress of a community are affected by the success or failure of its crops. It is desirable for the production of crops to be such that the producer will receive a reasonable profit and that the price to the consumer will be fair. Either overproduction or underproduction may prove disastrous first to the farmer and later to the nation. The amount of crops produced or the relative price received for them, or both, may affect the general business of the country in several ways: (1) Crops

influence to a large extent the buying power of a community. (2) The solvency of farmers and those associated with them in business ways depends upon the profitableness of crop production. (3) The export trade depends to a great extent on the amount of crops produced. (4) Transportation interests are influenced by the size and distribution of crops. (5) Industries using crops as raw materials are affected by the amount of crops.

Farmers are well aware of the necessity, if they are to prosper, of producing crops that are in demand and that fit into the economy of the area. They frequently knowingly follow rotations and other practices that are temporarily expedient but are unsound on a long-time basis. In the tobacco and cotton regions, too much of these crops have been grown, from the standpoint of the welfare of the land. Farmers sacrificed the soil in growing them, for in so doing they could get more money that they had to have, than by following other practices. In the Corn Belt and in the wheat regions, the same situation occurs. In farming the only item that the farmer has for sale is plant food (soil fertility) and labor. They constitute his bank account. And the decision that must be made is the extent to which to draw on it in the present and in the future. When times are hard the farmer usually depletes it and then replenishes it in good times for greater usefulness and for the "rainy day" that will surely come, if not in his day, in that of some future generation that receives the land as a heritage.

Crops the Most Important and Cheapest Source of Food. With the increase in population the tendency has been to decrease the number of animals used for food and to increase the acreage planted to crops. It requires more land to produce livestock than to grow grain. In other words, more food can usually be secured in the form of crops, from a given acreage, than in the form of animals.

Factors Influencing the Price of Crops. Among the factors affecting the price of crops may be mentioned (1) the supply on hand, (2) the prospective current production, and (3) the buying power of the consumer.

The Supply on Hand. Unduly large supplies of crops carried over from one harvest season to the next cause a reduction in price per unit, whereas a smaller supply than usual causes prices to advance. Since even a small surplus or deficiency of any crop creates among consumers a "bearish" or a "bullish" spirit, as the case may be, changes in the supply on hand necessarily affect prices.

The Prospective Current Production. Government statistics, crop-outlook reports, and private statistical information keep the buyer well informed as to acreage planted and crop conditions at any given time. If acreage planted and favorable weather conditions indicate that the

crop will be above the average, buying is curtailed and prices fall. On the other hand, if indications are that the crop will be below the average, there is active competition for available supplies, and prices advance.

The Buying Power of the Consumer. Although supplies on hand may be below normal and prospective yields less than the average, crop prices do not necessarily advance if the consumer's ability to buy is below normal. In periods of general depression, people eat less, buy less clothing, consume fewer luxuries, waste less, and produce more products for home consumption. In periods of prosperity, when buying power is high, they maintain a higher standard of living, eating more of higher priced foods, wasting lower quality products, discarding worn clothing sooner, and consuming larger quantities of luxuries. All these factors have an important bearing on current demand and resulting price of crops.

Future Production of Cheap Food. With increasing population the question of cheap food for the future is an important consideration. In order to produce crops profitably and at the same time furnish them to the consumer at a reasonable price, there are several things worthy of consideration. Among these factors may be mentioned (1) maintenance of the productivity of the soil, (2) the use of improved cultural methods, (3) the use of good seeds of improved varieties, (4) the control of insect pests and diseases, and (5) the economic use of labor.

Maintenance of the Productivity of the Soil. A productive soil is of first importance in the economic production of crops. It is obviously necessary that land produce well before the largest profits can be secured. The farmer who farms highly productive land is less affected by extreme fluctuations in crop values and variations of seasons than one who farms less productive land. Within certain limits the unit cost of production decreases as the acre yield increases. Even under very adverse climatic conditions, a fair crop may be secured from very productive soil.

Improved Cultural Methods. Good cultural methods are necessary for high production. Proper culture aids in the liberation of plant nutrients, the aeration of the soil, the conservation of soil moisture, the destruction of weeds, and the prevention of erosion. Good methods should be used from the time the preparation of the land is begun until the crop no longer needs cultivation.

Improved Varieties. The use of good seeds of high-yielding adapted varieties is one of the best means of producing large crops. It is evident that the quality and preparation of the soil cannot overcome the serious consequencies arising from the use of poor seeds. The differences in yield between varieties is often sufficiently great to determine whether the crop will be produced at a profit or at a loss.

Control of Crop Enemies. The damage done to crops by certain

enemies is enormous. The Hessian fly probably reduces the yield of wheat one-tenth on the average, and often the percentage of loss is higher. Corn is frequently badly affected by the chinch bug and the corn-ear worm. The grasses and forage crops are reduced in yield by such insects as cutworms, wireworms, white grubs, grasshoppers, and other insect enemies. Cotton yields are greatly reduced by the boll weevil, bollworm, and leafworm. The flea beetle, budworm, and hornworm often greatly reduce the yields of tobacco. Stored products are subject to damage by insects. The losses are difficult to estimate, but they will reach high percentages. It is estimated that 10 per cent of each of the following crops are lost annually on account of insect pests: cereals, hay and forage, cotton, and tobacco. These losses can be very materially reduced by the wiser use of control methods.

Economy of Labor. High labor costs and the difficulty of securing satisfactory workers have resulted in greatly increased use of machinery in the United States. Here are some examples. In 1929 there were 8,620 corn pickers manufactured in this country, and in 1945 the number was 35,885. Grain binders have decreased in number manufactured from 65,069 in 1929 to 9,054 in 1945, whereas combines have increased from 36,957 in 1929 to 51,418 in 1945. The use of combines eliminates much hand labor necessary when binders are used. There were only 1,464 pickup hay balers made in 1940, compared with 12,535 in 1945; none were reported made prior to 1940.

In 1939, 15 per cent of the hay was cut with tractor mowers, but in 1944 the percentage had increased to 42. The windrow pickup baler was used to bale 2.5 per cent of the hay in 1939, and 13.8 per cent in 1944. The need to conserve hand labor and to get work done on time were the reasons for the changes.

In 1944, in the United States, 50 per cent of all farm work was spent on crops, about 35 per cent on livestock, and 15 per cent on farm maintenance. Of the amount spent on crops, about one-half was spent on corn, cotton, and truck crops.

In the production of corn in 1944, for the country as a whole, preparation of the land and planting, cultivation, and harvesting made up better than one-half of the total cost of \$35.49 per acre. With cotton these operations were responsible for about two-thirds of the total cost of \$63.71 per acre. In the case of wheat, of the total production cost of \$20.41 per acre, preparation of the land, seeding, and harvesting made up over two-fifths of the cost. All these operations make heavy demands on labor.

Relation of General High Production to Profit. The almost invariable slump that comes in the prices of crops, whenever even a slightly larger

production than the normal for the United States is obtained, would seem to indicate that the methods now used are good enough and that improved methods are not necessary. A glance at the figures given in U.S. Department of Agriculture publications will show that a large production of any of the staple crops for the United States is usually accompanied by a lower price per unit of measure and a lower acre value. With intensively cultivated crops, such as tobacco and potatoes, this is particularly striking. It is so much so that every tobacco and potato farmer realizes that there is nothing more disastrous to profits than for the country as a whole to produce a very large crop. This would indicate that the crops produced in a normal year in the United States are sufficient to meet the market demands and that an abnormally large crop gives a supply in excess of the demands, which results in a lack of competition for products in the markets and a corresponding decline in prices.

This condition can be remedied to a certain extent by better systems of marketing. At the present time most of our crops are placed on the market as soon as they are harvested. In cases of very large crops this brings about gluts, due to inability of the small markets to handle and store such unusual amounts. These gluts always result in a decided break in the price. Better systems of marketing will avoid these gluts and their disastrous results by storing products and placing them on the markets more opportunely. However, there is no system of marketing that will sell at a high price all of a crop that exceeds the demand.

In 1932 the farmers of the United States produced 2,930,352,000 bushels of corn, and the farm value was $926,700,000 or 31.6 cents per bushel. In 1946 corn production totaled 3,287,927,000 bushels, and the farm value was $4,504,460,000, or $1.37 per bushel. In 1932, the acreage harvested was 110,577,000, and the average yield was 26.5 bushels. In 1946 the acreage harvested was 88,718,000 acres, and the average yield was 37.1 bushels. Thus, on about 20 per cent fewer acres in 1946, a corn crop was produced at a value of about five times as much as that of 1932.

In 1932 the country was in the throes of an economic depression, and there was little demand for corn although there was great need for it. In 1946 dollars were plentiful and the demand was strong, and the record corn crop of the nation had the record farm value, based on price.

Relation of Individual High Production to Profit. Although the preceding paragraphs show that an exceptionally large production of any crop for the country as a whole will create a supply greater than the demand and will usually result in lower returns per acre, profits for the individual are absolutely dependent upon yields that are higher than the average. No system of marketing under present conditions can make a 14-bushel crop of wheat or a 20-bushel crop of corn very profitable.

With usual prices of labor, seed, fertilizer, land, and farm products, it takes 10 to 15 bushels of wheat and 20 to 30 bushels of corn to pay the cost of production. Manifestly, the individual farmer who does not produce yields higher than these cannot expect to make a comfortable living.

Warren and Livermore[2] show that of 1,317 farms in one county in New York, 13 made labor incomes of over $2,000. The crop yields on these farms averaged 27 per cent higher than the average for the region. The average yields of crops for the region were hay 1.3 tons, oats 33 bushels, and potatoes 120 bushels. The average yields on the most profitable farms were hay 1.6 tons, oats 43 bushels, and potatoes 219 bushels. In another New York county, out of 671 farms, 19 made labor incomes of over $2,500. The crop yields on these 19 best farms were 18 per cent higher than the average, even though the yields in this county were exceptionally good and far above the average for the state. Although other factors doubtless help to make these farms successful, these figures indicate a strong relation between high production and high profits.

During the 10-year period 1934–1943 the average net cost per bushel for producing corn was $1.22 for the United States, but only 84 cents for Illinois and Iowa. The difference was due largely to higher yield per acre. During the same period the net cost per bushel for producing oats in the country as a whole was 75 cents, but only 70 cents in Illinois and Iowa, and 67 cents in Michigan, Wisconsin, and Minnesota. The higher yields per acre in these states were an important factor in reducing costs per bushel.

Although it takes many things other than high production to ensure profits from farming, it is hardly possible to make large labor incomes on farms where the average crop yields are not well above the average for the region.

Most Productive Methods Not Necessarily the Most Profitable. At a given price per unit measure of product, after a certain yield is reached with any crop, the profits from further intensive methods of culture begin to diminish; and if too great a degree of intensity is practiced, the increased cost of production may become greater than the value of the increased crop produced thereby. Just how far it is advisable to increase yields by better methods is a practical problem. It is said that one of the largest yields of corn ever made in the United States was produced at a loss, if the crop alone had been the only source of income. This corn crop produced more than 200 bushels to the acre, but the producer used the most intensive systems of fertilizing and cultivating. A system of irrigation was installed to ensure an optimum amount of water for the crop at all times. The total cost per acre for

producing this crop is said to have been something over $500. The corn from this acre would have had to sell for a very high price to pay the cost of production, but the farmer who grew it won $1,000 in prizes. So the end justified the means. However, no farmer who has to sell his crop for the usual market price would be justified in using the methods followed by this individual. The proper degree of intensity to be used in crop production can be found only by an accurate determination of the point where increased intensity fails to pay. A given number of cultivations may pay well on a crop, and additional cultivations may further increase yields, yet the increased yield due to the additional cultivations may not be sufficient to pay for their cost. In like manner, the application of a certain amount of a certain kind of fertilizer may be necessary to ensure profits from a crop, and larger amounts or better grades of fertilizers may materially increase yields, yet their use is not justified unless they more than pay the extra expenses incurred. It should be remembered that not only do the expenses involved in using a fertilizer include the cost of the fertilizer, but they also include the cost of hauling and distributing the fertilizer, and of harvesting, storing, and marketing the extra crop produced.

The degree of intensity to be practiced in producing crops is governed largely by the selling price of the products. When the prices of crops are high, a considerable expense is justified in their production, but, when prices are very low, the point of diminishing returns from intensified methods is reached very quickly.

The object of the farmer should not be to produce the largest yield possible to the acre, but to obtain the largest *economic* yield. And further, the aim should be to make the greatest net return per farm rather than per acre, for the entire farm and not a single acre is the family unit. Economically productive acres, however, help to make economically productive farmers and farming profitable.

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Topics for Discussion

1. Do questions of present-day economics change fundamental teachings in reference to crop production?

2. Should the unit of measure for a farmer be production per acre or production per farm?

3. Is control of crop production fundamentally wrong?

4. In periods of low prices, should acreages of crops on individual farms be increased or decreased?

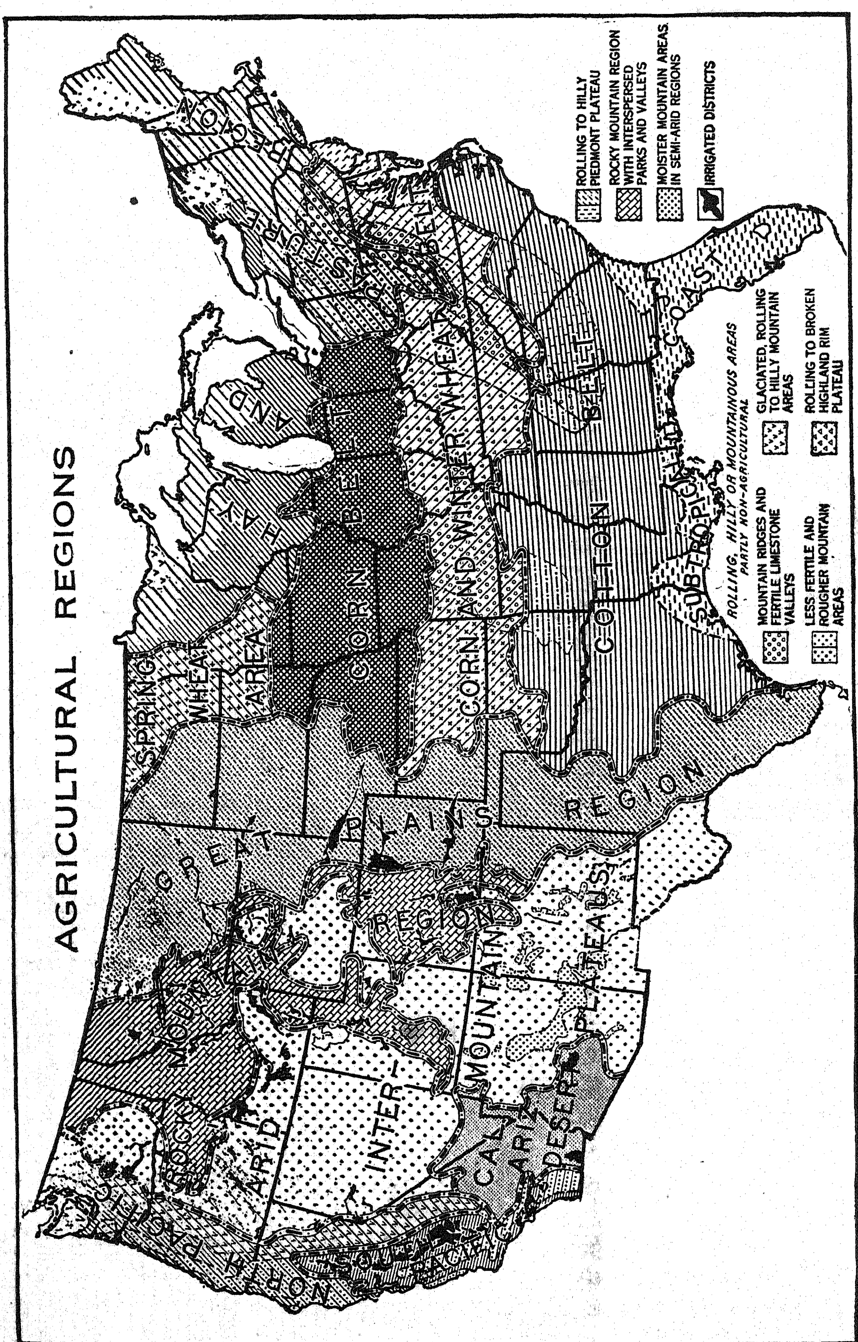

FIG. 2. Outline map of the United States showing agricultural regions. (*U.S. Dept. Agr. Yearbook*, 1921.)

CHAPTER III

ADAPTATION OF CROPS

As a general rule crops are not profitable unless they are well adapted to the region in which they are produced. In other words, if the average farmer is to raise crops successfully, the crops must be productive and easy to grow under the existing conditions.

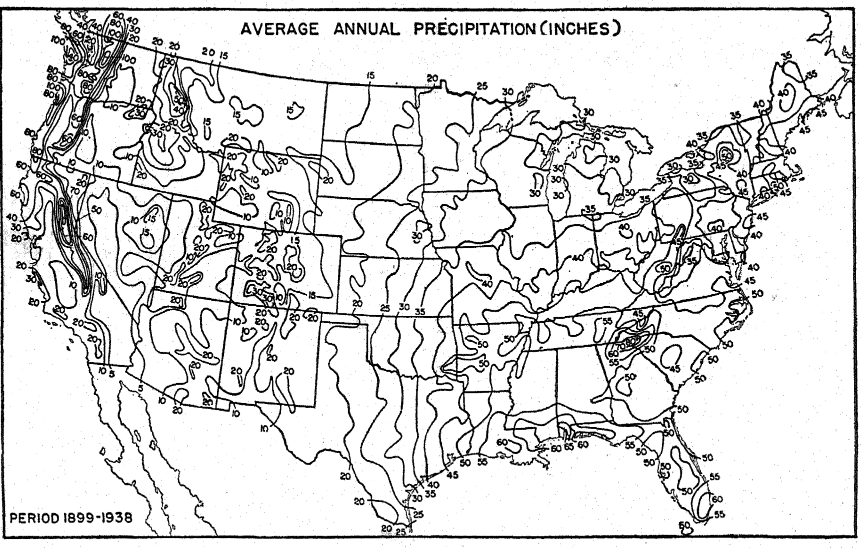

Fig. 3. Average annual precipitation in inches for the United States for the period 1899–1939. (*U.S. Dept. Agr. Yearbook*, 1941, *U.S. Weather Bureau.*)

There are three groups of factors that determine whether certain crops can be economically produced in given regions, namely, climate, soil, and economic conditions.

A study of Figs. 2, 3, and 4, showing United States maps of agricultural regions, distribution of rainfall, and length of growing season, will give the reader an idea of the variations in climate that exist in this country and will partly explain the reasons that certain crops are adapted to certain regions.

Examples of Crop Adaptation. Cotton is grown in the southern states. About two-thirds of the tobacco is raised in the states of North

Carolina, Kentucky, and Virginia. Peanut production is limited largely to the southern states bordering on the Atlantic and Gulf coasts. Corn is primarily the crop of the corn belt, about one-half of the acreage being in four states, namely, Iowa, Illinois, Nebraska, and Minnesota. In the case wheat, four states— Kansas, North Dakota, Oklahoma, and Texas—have two-fifths of the total acreage of the country. The three states of North Dakota, South Dakota, and Montana produce practically all the spring wheat grown in the United States. Oats yield much better in the North than in the South. Cowpeas and soybeans, on the other hand, thrive more luxuriantly in the South than in the North. The hay and pasture grasses grow better in the cooler sections, other things being equal, than in the warmer sections. However, certain grasses, such as Johnson grass and Bermuda grass, are peculiarly adapted to the South, whereas timothy and the bent grasses are adapted to the North. Kentucky bluegrass thrives best in the rich limestone regions of the country. The sorghums are produced to the greatest extent in the regions where the rainfall is light and the summers are hot. Buckwheat is produced almost entirely east of the Mississippi River, and then practically always on the hilly and mountainous lands. Thus, certain crops are more or less sharply confined to certain regions of the United States.

FACTORS DETERMINING THE ADAPTATION OF CROPS

The distribution of crops is determined largely by their adaptations. If the climate and soil conditions are favorable for the requirements of the crops, then, other things being equal, they can be successfully and profitably grown. However, an important factor to be considered is the economic conditions prevailing in particular sections. The mere fact that a particular crop is suited to the soil and climate does not prove that it should be grown. It is necessary to consider such items as transportation facilities, distance to market, market demand and supply, capital required, labor supply, etc.

The adaptation of crops to climate is shown by the fact that certain plants are indigenous to the tropical region, others to the frigid, and still others to the temperate, although the soil conditions may be practically the same.

In case of adaptation of crops to soils, the importance of this relation is second only to the climatic factor.

Thus, the four factors determining the desirability of growing any crop in a particular region are (1) the adaptation of the crop, (2) the climatic condition of the region, (3) the soil condition of the region, and (4) the economic situation.

Crop Adaptation. In regions to which certain crops are especially adapted, the first evidence of special adaptability is usually shown by the number of farmers growing those particular crops, and also by the fairly good yields produced on even the rough, hilly, and comparatively poor lands. Of these crops, of which there are usually a number of varieties, the plants are above the ordinary in size and luxuriance of growth. On the other hand, as these crops are removed from their favorable environment, the converse is found.

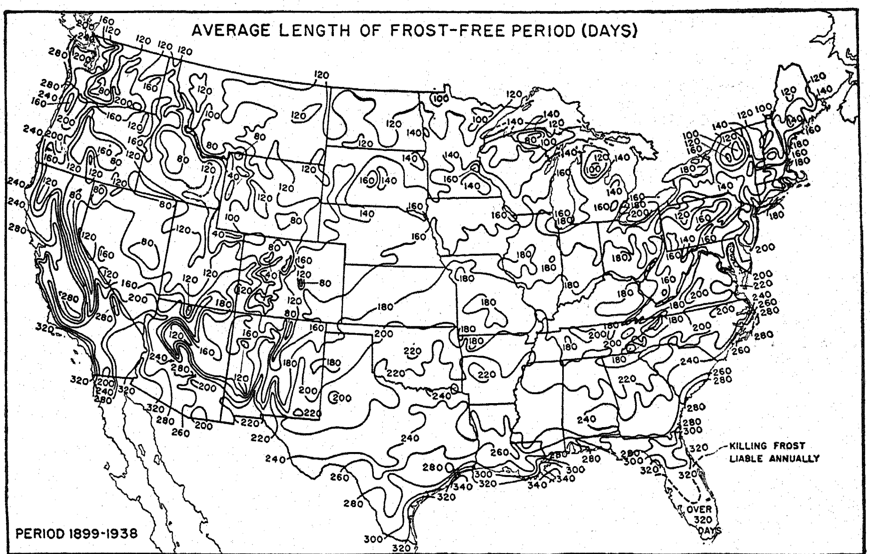

FIG. 4. Average length of frost-free period shown in total number of days in the United States for the period 1899–1938. (*U.S. Dept. Agr. Yearbook*, 1941, *U.S. Weather Bureau.*)

As crops are farther removed from the regions of especially favorable climate, more attention on the part of the farmer is necessary. They must be grown on the richest land, given good cultivation, and treated indulgently in many ways. The struggle for existence in competition with the better adapted plants becomes severe, and frequently, unless aided by man, the introduced crops fail to survive for any great length of time.

The Climatic Requirements for Certain Crops. The climatic requirements for crops are even more exacting than the soil requirements. Nature has equipped certain crops for resisting droughts; others thrive under excessively moist conditions. Some luxuriate under the burning sun of the tropics, whereas others give optimum returns only in temperate climates.

Corn. The corn crop does best in sections where rainfall is abundant,

nights warm, days mostly warm and bright, and the frost-free period 125 to 150 days. Varieties and strains of corn have been developed for every section of the United States where there is sufficient rainfall, but the bulk of the corn crop is produced in the upper Mississippi Valley, where the climatic conditions are those enumerated above (Jenkins[1]).

Wheat. Wheat is grown mostly in regions where the winters are cold, although there are some notable exceptions, such as California, Egypt, and India. Practically three-fourths of the wheat crop of the United States is grown where the average January temperature is below freezing and where the mean annual temperature is between 45 and 60°F. However, taking the world as a whole, we find that wheat has a very wide climatic range and that this range is being extended by climatic adaptations. Weather affects both growth and quality in wheat, a high moisture content in the soil during the early stages of growth is conducive to tillering and a cool spring is most favorable to largest yields of best quality grain. Those localities which have extremes of temperature and rainfall generally produce the hardest and reddest grains; but sunny climates, with moderately dry weather during the ripening period, make brighter grains, which in turn produce a higher quality of flour (Salmon[2]).

Oats. Oats do best in cool, moist climates. If ample water is provided, the crop may be successfully grown in rather warm climates, but the oat crop requires more water per pound of dry matter produced than any of the other important cereals. About half of the oat crop of the United States is produced in those states bordering on the Great Lakes. Winter oats are grown chiefly in the South. The crop is sown in the early fall and ripens in the early summer, thus having for a growing season that part of the year when the season is cool and moisture abundant.

Potatoes. The climatic requirements for the potato crop are very similar to those for oats. Potatoes require cool, moist weather for best development. The enormous potato yields of certain European countries is due more to a favorable climate than to soil conditions and cultural methods. The chief potato-growing sections of the United States are north of the best corn lands. The potato crop of the South is made possible by very early spring planting. In this way the crop matures before hot weather comes, or the crop is planted in late summer to mature during the cool weather of autumn.

Cotton. This crop requires a long growing season with hot days and nights. It is a common saying in the South that cotton never grows well until the nights get too hot for sleeping under cover. Protracted rainy spells are unfavorable to the growth of cotton. Occasional showers followed by bright, hot weather afford ideal weather conditions for the

crop. The southern part of the United States has almost ideal weather conditions for cotton, producing approximately one-half of the cotton crop of the world.

Grasses and Clovers. There are good grasses and clovers for all climates. In the United States timothy, red clover, and Kentucky bluegrass thrive luxuriantly in the cool, moist climate of the northeastern section. Farther south these plants become less important, except in the higher altitudes, and they are supplemented by Bermuda grass, Johnson grass, lespedeza, and carpet grass, which will withstand the hot, dry periods common to the southern region.

Practically all crops are rather limited in their adaptation to climatic conditions, but the illustrations will suffice to show the importance of this relation.

The limits of practical adaptation may be extended by the development of new strains and varieties, as illustrated by alfalfa. In the United States three broad groups of alfalfa are recognized—hardy, medium hardy, and nonhardy.

Choice of Soil to Suit Crop Needs. The external factors of plant growth are (1) mechanical support, (2) air, (3) heat, (4) light, (5) water, and (6) nutrients. With the exception of light, the soil supplies all these, either wholly or partly. Not all soils are alike in their ability to supply these factors, and different kinds of plants vary in the degree of their requirements. For this reason one of the duties of the farmer is to find the crop particularly adapted to his soil.

Kind of Soil Required. From observations and experiments it has been found that certain crops are adapted to certain kinds of soil. As a rule, the small-grain and grass crops flourish most luxuriantly on the heavier classes of soil, such as clays and clay loams. Corn, however, does best on loams and silt loams, while potatoes and truck crops give best results when planted on loams or sandy loams. Of course we do not mean that these crops cannot be grown profitably on other soils, but that, other things being equal, they will give best results on the soils mentioned. Crops requiring a large amount of cultivation usually give best results on the soils of coarser texture, as these soils are more easily worked and are less affected by rains and dry weather. Such soils are usually called "light" soils on account of the fact that they are more easily worked, though their volume weight may be heavier than that of the finer textured soils. The potato crop may be cited as a crop that is usually grown on the lighter soils, even though it often gives splendid yields on heavier soils. In the case of this crop, farmers prefer light soils, since the soil must be worked a number of times in planting, cultivating, and digging, and this work is more easily and cheaply accomplished on light than on

heavy soils. This is one reason why truck crops, which require a large amount of cultivation, are usually grown on light soils. On the other hand, grasses and small grains require no cultivation after seeding and can, therefore, be profitably grown on heavy soils. Generally speaking, heavy soils contain more plant nutrients than light soils and give more profitable returns from those crops which do not require much cultivation of the soil.

Soil Water. The water-holding capacity of soils has a great influence upon the profitableness of crops that may be grown upon them. For example, grains and grasses do best on soils of high water-holding capacity, whereas cotton, peanuts, and tobacco do best on easily drained soils.

Soil Heat. The warmth of soils is largely dependent upon their water-holding capacity. This is another reason why truck crops that must mature early to be most profitable are usually grown on soils that dry out quickly. The drier, coarser textured soils become warm early in the spring; thus the crops get a quicker start and therefore mature earlier.

Soil Nutrients and Organic Matter. The supply of soil nutrients and organic matter is important. Tobacco must be well supplied with the plant nutrients, but the highest quality of bright or flue-cured tobacco is produced on soils low in organic matter. With sun-cured, dark or shipping, and Burley tobacco an abundant supply of both nutrients and organic matter is desirable. The best corn lands are well supplied with plant nutrients and organic matter, and the same is true of wheat. Waller[3] states that the spring wheat center has its present location because of the great level expanse of rich soil left after lowering of Lake Agassiz.

Modification of Soil and Climate for Crop Needs. It is often advisable to modify conditions to meet the special adaptations of plants. Corn, which is especially adapted to the corn belt, is grown in all parts of the country, but in such sections as New York, eastern Pennsylvania, and the New England states, the crop should be planted only on the best lands and should be especially well cultivated.

In the case of cold frames, greenhouses, and small vegetable gardens, where the products grown have a high value, both soil and climatic factors may be profitably modified to suit the adaptation of the plants. It has been found that many plants can be brought under cultivation with comparative ease if the soil reaction is so modified that it approximates that of the soil in which the plants grow in nature. In the semi-arid and arid sections of the country, irrigation has made practicable the profitable production of certain crops, one instance being alfalfa. Drainage is another factor that has made possible the profitable production

of crops on certain soils. Terracing of soils, especially those of the South, has aided in reducing erosion and in a great measure maintains the productivity of these soils. The ridging of some soils for such crops as cotton and corn, where the soil tends to be wet, makes the production of these crops feasible. Another practice, the reverse of ridging, is listing. This practice, which is followed in the drier sections of the country, allows the seeds to be placed nearer the soil water. The judicious use of organic matter and fertilizers is important in changing soil conditions and meeting the needs of certain crops. As an instance, cotton may be mentioned. With the increasing ravages of the boll weevil, cotton production is being extended into other sections less favorable to its production, and the climatic limitations are being partly overcome by the practice of better soil management.

Thus, by modifying to some extent the climatic factors through control of temperature, as in greenhouses, and by supplying moisture, as in the case of irrigation, the farmer can meet within limits the requirements for adaptation of plants. Also the soil requirements of the plants can likewise be modified within limits by the judicious addition of fertilizers and organic matter, by proper liming, by drainage when advisable, by terracing where practicable, by ridging when necessary, and by listing when expedient.

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Topics for Discussion

1. Why is the acre yield of potatoes larger in Ireland than in Maine?

2. Why has the South never become a great livestock section?

3. Why is truck-crop production in the United States largely concentrated in coast states?

4. Is it usually wise for a farmer to grow essentially the same type of crops as those grown by his near neighbors?

CHAPTER IV

CLASSIFICATION OF FIELD CROPS

The term "field crops," as used in this book, includes all herbaceous plants grown in cultivated fields under a more or less extensive system of culture. In contrast to these kinds of crops, "horticultural crops" may be defined as those crops which are grown under systems of intensive culture in relatively small areas. Under the latter head fall such crops as fruits and vegetables. However, this distinction does not always hold true; fruits may be grown over large areas, and root crops and tobacco require rather intensive cultivation.

Terminology. It is highly desirable in the discussion of agronomic questions to use a uniform and common terminology. The fact that agronomy is a young science may explain to some extent the differences in existing terminology.

CLASSIFICATION

It is hardly possible to give a classification of field crops that will hold under all conditions. Certain plants are constantly being put to new uses, and many crops are used for a number of purposes.

The classification will depend largely upon the point of view of the reader. Since crops are used for so many different purposes and vary so widely in their botanical relationship, they must be arranged into various groups. Field crops may be grouped from a *botanical* standpoint. In such a grouping the plants are arranged in their evident relationships according to similarity of parts. In order to carry on such a study expeditiously and accurately, a knowledge of the principles of systematic botany is necessary. Again, from an *agronomic* standpoint field crops may be grouped according to their special uses. In such a classification the botanical relationships are not much regarded. Plants that differ widely botanically may be placed in the same group. For example, forage crops include both grasses and legumes. Field crops may be still further classified as *special-purpose* crops. In such a grouping may be included any crop that is used for some special purpose. Rye, for instance, which is generally used for grain purposes, is sometimes used for green manuring. When so used it has a special purpose and should not in this instance be considered under grain crops.

Botanical Classification. With a few exceptions the important field crops belong to two families, namely, the *Gramineae*, or grass family, and the *Leguminosae*, or legume family. The potato and tobacco belong to the nightshade family, *Solanaceae;* cotton to the mallow family, *Malvaceae;* flax to the flax family, *Linaceae;* and hemp to the nettle family, *Urticaceae.*

Grass Family. The grass family includes practically three-fourths the cultivated forage crops and all the cereals. Of the 6,000 known species of grasses, about 1,380 are grown in the United States.

The grasses are characterized botanically by having alternate leaves with parallel veins and jointed, usually hollow, cylindrical stems, with cross partitions at the nodes. The basal portion of the leaf, or sheath, encloses the stem, the sheath being open on the side opposite the blade. Where the blade of the leaf joins the sheath is usually found a peculiar appendage known as the "ligule." The majority of the grasses are wind pollinated, but there are some exceptions. For example, oats and wheat are normally self-pollinated. The agricultural grasses include *annuals*, persisting for only a single season, and *perennials*, persisting for more than 2 years. Under the annual grasses may be mentioned the cereals, and under the perennial grasses Kentucky bluegrass, Bermuda grass, and Johnson grass. The roots of all grasses are very slender and have few branches, and, even in case of perennial forms, new roots are formed each year.

Legume Family. The legume, or pulse, family ranks next in importance to the grass family. This group is distinguished botanically by having alternate compound leaves with stipules. The flowers of field-crop legumes are papilionaceous (butterflylike), as illustrated by the pea flower. The pistil is simple, in fruit becoming a legume, and the embryo usually completely fills the seed. Legumes have been so named from the fact that the seeds are borne in pods each consisting of one compartment containing sometimes one seed, but usually several, as illustrated by the bean. The inflorescence is usually in axillary racemes, as in case of soybeans, vetches, and peas, or in heads, as in case of the true clovers. The inflorescence of alfalfa is a spikelike raceme.

The agricultural legumes include annuals, biennials, and perennials. The annuals may be subdivided into *summer annuals*, such as soybeans, and *winter annuals*, such as crimson clover. *Biennials* persist for two seasons, such as sweet clover and most strains of red clover. Examples of *perennials* are alfalfa, ladino, white, and alsike clovers.

The roots of the legumes characteristically bear enlargements, called "nodules," which are caused by the activity of the specific bacterium *Bacterium radicicola.* Each nodule contains a number of

bacteria having the power of assimilating atmospheric nitrogen. The activity of these organisms accounts for the great agricultural importance of legumes.

Nightshade Family. In the nightshade family (*Solanaceae*) are found the potato, tobacco, tomato, and other plants of great economic importance. This family also contains many plants that are deadly poisonous.

Agronomic Classification. Under this head field crops are classified according to use rather than according to similarity of parts. On this principle, the following classification is often found:

1. *Cereal or Grain Crops.* A cereal may be defined as any grass grown for its edible grain. The term may refer either to the plant as a whole or to the grain itself. Under such a definition buckwheat is not a cereal, as it does not belong to the grass family. It is, however, usually so classed since the grain is used like the true cereals. "Grain" is a collective term for the fruit of cereals. The six great cereals of the world are wheat, rye, barley, corn, oats, and rice. In some countries the millets and nonsaccharine sorghums are produced for their seeds. In the United States, corn, wheat, and oats occupy by far the greatest part of the cultivated area occupied by cereals.

2. *Legumes for Seed.* The term "legume" may be defined as a plant of the natural family *Leguminosae.* It is also used to refer to the pod of a leguminous plant, consisting of one carpel and usually dehiscent by both sutures. The principal legumes raised for their seeds are field beans, field peas, peanuts, cowpeas, and soybeans.

3. *Forage Crops.* The term "forage" may be defined as vegetable matter, fresh or preserved, utilized as feed for animals. Forage crops include all grasses cut for hay, legumes cut for forage, sorghum, and corn fodder.

Among the grasses the chief forage crops are corn, sorghum, millet, oats, barley, and certain hay and pasture plants, such as timothy and Kentucky bluegrass. Of the legumes, the clover species, such as common red, mammoth or sapling, and alsike are largely used for hay. Cowpeas and soybeans are important annual hay legumes. The above legumes are often used for pasture purposes, whereas white or Dutch clover and lespedeza may be classed as distinctively pasture legumes.

4. *Root Crops.* A root crop is one grown for its enlarged roots. In this group are found such plants as turnips, rutabagas, and various forms of the beet. Sweet potatoes are grown to a large extent in the southern part of the United States. The sweet potato is a true root crop, whereas the potato is not. Many root crops such as turnips, rutabagas, mangels, and carrots are far less grown in the United States than in

Canada and Europe. In Great Britain, Canada, and certain European countries, root crops are grown to a great extent.

5. *Fiber Crops.* Fiber crops are grown for their fiber, which is used in making textiles, ropes, twine, and similar materials. The principal fiber plants of the United States are cotton, flax, and hemp. Cotton is by far the most important of the fiber plants, and its great acreage and value give to the fiber group the third rank in importance. Ramie, jute, and sisal are also sources of fiber.

6. *Tubers.* The tuber is a much thickened underground stem, developed on a slender leafless shoot or stem. The only tuber of importance cultivated in the United States is the potato. It comprises about 25 per cent of the food of the European and English-speaking peoples. In European countries the potato is grown more extensively, gives larger yields, and has a much greater per capita consumption than in the United States. The Jerusalem artichoke and the chufa are also grown for their tubers.

7. *Sugar Plants.* The principal plants grown for their sugar are sugar cane and sugar beets. The area suitable for the production of sugar cane in the United States is rather limited; the area suitable for the growing of sugar beets is much larger. The bulk of the sugar produced in the United States comes from sugar beets, but most of the sugar consumed in this country is imported because the local supply is insufficient. In addition to this crop, the saccharine sorghums are used for making sirup.

8. *Stimulants.* Under this head may be included such crops as tobacco, tea, and coffee, and of these crops tobacco is by far the most important in the United States.

There are other crops extensively grown in the United States, such as fruits, vegetables, and timber crops, which are not commonly classed as field crops.

Special-purpose Classification. Many of the crops previously mentioned are well suited for more than one purpose. The name of the group is often derived from the purpose for which the crop is used. Some of the special-purpose groups are as follows:

1. *Cover crops* are those crops which are seeded so as to make a growth to cover or protect the soil. If a crop serves as a cover crop and is then turned under, it becomes also a green-manuring crop. Some of the plants widely used for cover crops are rye, vetch, and crimson clover.

2. *Green-manure crops* are those crops which are grown to be plowed under or to be disked into the soil to increase its productivity. As a rule legumes are more desirable than nonlegumes for this purpose, as they

often add nitrogen to the soil. Such crops as soybeans, cowpeas, vetches, clovers, rye, and buckwheat are used for this purpose.

3. *Catch or emergency crops* are crops used as substitutes for staple crops that have failed on account of unfavorable conditions. They are usually quick-growing crops, such as rye, millet, and buckwheat. If corn land is seeded to rye in the fall and the rye turned under in the spring and the land is seeded to some other crop, rye could in such an instance

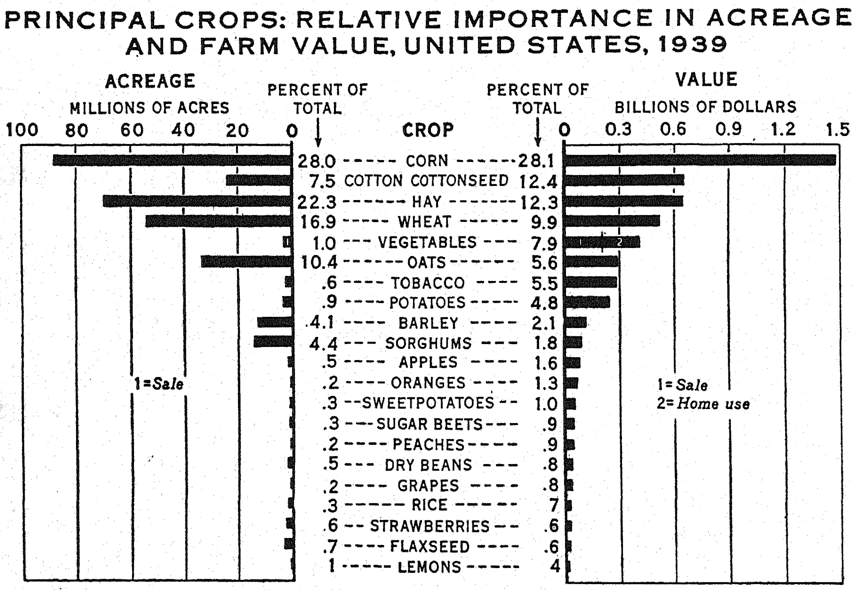

FIG. 5. Relative importance of crops in the United States.

be considered a catch crop. It could at the same time serve as a cover, green-manure, and pasture crop.

4. *Soiling crops* are those crops cut green and fed green directly from the field. Thus, alfalfa, if cut and fed green to animals in the stable or feed lot, becomes a soiling crop. Next to pasturing this is the most primitive way of feeding animals.

5. *Silage crops* are those crops preserved in a succulent condition by partial fermentation in a tight receptacle. The terms "silage" and "ensilage" are synonymous. The chief silage crop of the United States is corn. However, in those sections where the rainfall is insufficient for growing corn, sorghum is extensively used for silage. Other silage crops are soybeans, cowpeas, clovers, hay grasses, and sunflowers.

6. *Nurse or companion crops* are those used to protect some other

crop sown with them. Grasses and clovers are often sown with grain crops.

Topics for Discussion

1. What classes of crops are most widely distributed over the United States?

2. In what section of the United States is each agronomic class produced most extensively?

3. Where is the greatest concentration of each class in your state?

4. Which class is most important from (*a*) a food standpoint; (*b*) soil-fertility maintenance; (*c*) luxury point of view?

CHAPTER V

GERMINATION AND GROWTH

Means of reproduction are necessary for the perpetuation of all living organisms. In case of the ordinary cultivated field crops new generations are usually reproduced by means of seeds. In the production of crops it is necessary first to study the factors essential to the germination of seeds, as this process is one of the first steps concerned in plant growth. The seeds are used not only to reproduce the new generation of plants but frequently to furnish food for man and animals. In the seed the plant stores up food to be used at some future time. The corn plant stores up in the kernels food for the young plant to use, the potato in the tuber, and the sweet potato and the beet in the roots. It is this stored food, whether it be in seed, tuber, or root, that serves as food for the young plant until it is sufficiently developed to manufacture food for itself.

Seed Structure and Composition. The essential parts of seeds are as follows: (1) the young dormant plantlet or *embryo* or *germ;* (2) the stored food, which in the cereals is outside the embryo and known as the "endosperm," and in the legumes is in the cotyledons, a part of the embryo; and (3) the seed coat, a protective covering, which may consist of one or more layers.

In the cereals the endosperm is mostly starch, while the germ is high in protein, oil, and minerals. In the case of legumes the entire seed, which consists of the embryo and the seed coat, is relatively high in protein. The mineral constituents of various seeds are given by McCarthy[1] as follows: in red clover, 4.5 per cent; in rape seed, 4.44 per cent; in buckwheat seed, 1.37 per cent; in winter wheat, 1.97 per cent; in spring wheat, 2.14 per cent; and in corn, 1.51 per cent.

Qualities for Germination. In order that seeds may germinate perfectly, it is usually necessary that they be well developed and have vigorous germs and an abundant supply of stored food. In addition they should have been stored in such a way as to retain high viability and vitality. The superiority of well-developed seed of high quality over inferior seed is discussed in Chap. VII.

Duvel[2] found that the main factor affecting the vitality of seeds is their moisture content. He found that seeds retain their vitality well if thoroughly air-dried as soon as mature and kept in a dry place. It was

found that seeds with a high percentage of moisture deteriorate very quickly even when stored under dry conditions. Duvel[2] stored several different kinds of seeds, mostly vegetable, in paper envelopes and in corked bottles under different conditions at various places—San Juan, Puerto Rico; Lake City, Florida; Mobile, Alabama; Auburn, Alabama; Baton Rouge, Louisiana; Wagoner, Oklahoma; Durham, New Hampshire; and Ann Arbor, Michigan. The seeds were stored under the following conditions: (1) under trade conditions or in ordinary unheated rooms; (2) in dry rooms, *i.e.*, rooms in buildings that were heated during cold weather; and (3) in basements at comparatively low and uniform temperature and high relative humidity. When envelopes were used as seed containers, the average loss in germination after storage for 251 days under trade conditions was 36.63 per cent; in dry rooms, 21.19 per cent; and in basements, 42.28 per cent. When corked bottles were used, the average loss in germination was, under trade conditions, 3.92 per cent; in dry rooms, 8.08 per cent; and in basements, 4.51 per cent.

The results reported by Duvel[2] also show that seeds of high viability deteriorate less in storage than seeds of comparatively low viability.

Conditions Necessary for Germination. The three conditions necessary for germination are (1) sufficient moisture, (2) sufficient oxygen, and (3) sufficient heat. A certain interrelationship exists between these factors. The optimum amount or degree of any one of these factors will depend on the degree of the other two. It has been found that high temperature favors the germination of cocklebur seeds because of greater diffusion of oxygen under such conditions. A direct relationship of several factors, such as temperature, oxygen, and carbon dioxide, controls germination. Thus, in considering the optimum conditions for any one of the three factors, one must take into account the relations existing among them. It is, therefore, difficult to state the optimum condition for any one factor.

Moisture. At the North Carolina Experiment Station, McCarthy[1] found that the presence of a quantity of water sufficient to cause the seeds to swell is the first and most important requirement. Quoting from Nobbe he states that the water absorbed by wheat in swelling amounted to 60 per cent of the dry weight; by corn, 39.8 per cent; by white clover, 89 per cent; by alfalfa, 87.8 per cent; and by rape, 48.3 per cent.

Aeration. The necessity of oxygen for germination may be easily shown by experiment. If the soil is compact and waterlogged so that no air can reach the seeds, they will usually decay. This is one of the reasons for keeping soils well drained and aerated. However, rice and some other seeds will sprout in mud or water.

Temperature. The amount of heat required will vary with the kinds of seeds. Some seeds, such as those of clover and oats, will grow at a rather low temperature, while the temperature requirement for best growth is higher for the seeds of corn and beans.

McCarthy,[1] quoting from Sachs, states that the optimum temperature for germination of corn, beans, and pumpkins is 91°F., and for barley and wheat 84°F. The results also show that corn, German millet, and timothy seeds will not germinate at a temperature of 40°F., but that such seeds as winter wheat, alfalfa, red clover, and buckwheat show some germination at this temperature.

Process of Germination. The dry seed is in a dormant state, but, when it is placed in the proper environment, germination and growth begin. These processes start in most seeds within a few days after they are placed under favorable conditions. The radicle first emerges from the seed coat and grows downward, and soon the shoot axis, or plumule, breaks through and grows upward. In the process of growth the moisture taken up by the seed carries in solution part of the stored food which, if starch, is changed by enzymatic action into sugar. For a few days the young plant feeds upon the food furnished by the seed. When the plant reaches sunlight and new leaves begin to grow, a new set of permanent roots forms just below the surface of the ground. The plant now begins to feed upon the nutrients secured from the soil and from the food manufactured in the leaves and is no longer dependent upon the seed for sustenance.

Sources of the Elements Required for Growth. Ten elements have long been recognized as being necessary for plant growth. Others are equally important, as discussed in Chap. VIII. Of the ten elements, four are secured from the air and from water, namely, carbon, hydrogen, oxygen, and nitrogen. Nitrogen is taken from the air by certain groups of bacteria. The nitrogen thus assimilated by these organisms undergoes a change before it is used by higher plants. The nitrogen used by all plants comes directly or indirectly from the air. The bacteria taking nitrogen from the air may be associated with most, if not all, leguminous plants.

The mineral elements essential to plant growth come from the soil. The nitrogen, which is taken from the air by bacteria, is first combined in the soil to make soluble compounds before it can ordinarily be used by higher plants. Therefore, it is usually stated that seven elements come from the soil and three from air and water.

Throughout the inert mass of soil are to be found varying quantites of the essential elements in the form of chemical compounds. Through certain agencies the compounds gradually become soluble in water, and the plant nutrients are removed from the solution by the plants.

PARTS OF A PLANT

Ordinarily the plant is divided as follows: (1) the root system, (2) stem and leaves, and (3) the reproductive part, made up of flowers, fruits, and seeds.

The Root and Its Functions. Roots frequently make up one-half, or even more, of the weight of crop plants. The roots have two main

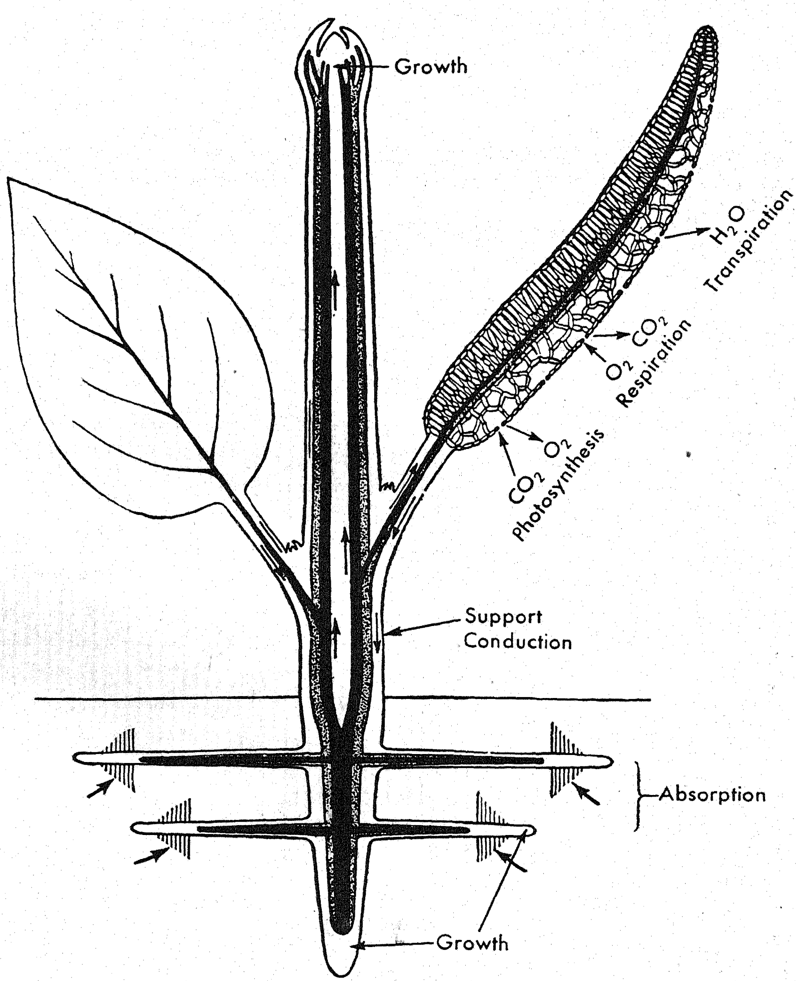

FIG. 6. Important structures and functions of the plant. Diagrammatic representation of roots, stems, leaves, and growing regions and their functions. Wood, solid black; phloem, dotted; pith and cortex, white. Arrows indicate movement of materials into the plant, along the stem, and to and from the leaves. One leaf is represented in section. Water passes from the root upward to stem and leaves through the wood. Manufactured food passes from the leaves both upward and downward through the phloem. The various gas exchanges between leaf and atmosphere are graphically represented. (*From Sinnott's "Botany: Principles and Problems,"* 1946.)

functions—to anchor the plant and to absorb water and plant nutrients from the soil.

Distribution of Roots. The permanent roots of cereals are fibrous and extend outward and downward in all directions from the nodes of the shortened internodes of the stems at or below the ground line. The region of the shortened internodes is called the "crown." In the case of wheat, the main roots may penetrate to a depth of 4 feet or more, sometimes 5 or 6 feet, and even as deep as 7 feet. Moreover, the extent of branching and rebranching allows great development of the root system. Wheat, in common with all grasses, does not develop a taproot.

King,[3] in Wisconsin, found in the case of corn that the permanent roots first spread laterally. After 9 days the roots extended both laterally and downward; at 18 days after planting some of the roots extended laterally 18 inches and downward about 12 inches. At 27 days after planting some of the roots had reached 24 inches laterally and 18 inches downward, with the tips 4 inches below the surface. At 6 inches from the hill no roots were nearer the surface than 2 inches. When the plants were 18 inches tall, 42 days after planting, the downward growth of the roots had reached 18 inches and the roots of two hills had met and passed each other in the center of the rows, which were 3½ feet apart. When the plants were 3 feet in height, the roots occupied the upper 2 feet of soil, which was as deep as they could be measured in the experiment. It has been shown, however, that, as the corn plant matures, the root system continues to increase and the soil is penetrated to a depth of 3 or 4 feet. Branch roots come nearer the surface of the soil as development continues, and near maturity many roots are close to the surface. Corn also develops aerial or brace roots that serve to brace the plant. After they enter the soil they also aid in nourishing the plants.

The roots of plants ramify through the soil in all directions. Some plants, such as alfalfa and most of the clovers, are classed as deep-rooted plants. Others, such as the pasture and hay grasses and corn, although comparatively shallow-rooted, produce a rather extensive lateral growth. As long as the plant is growing, new branch roots are being formed, and on the new roots are produced the *root hairs*. These root hairs live and function for only a short time, and as the roots extend new root hairs are produced. With few exceptions, the root hairs and not the roots absorb water and nutrients from the soil.

The root hairs are minute single-celled organs produced near the tips of the new roots. In other words, each root hair is essentially a single cell and consists of an elongated portion of one of the surface cells of the root. Like all typical cells, it consists of a distinct bit of living matter,

or *protoplasm,* with nucleus, sap cavity, and certain other structures, enclosed in a cell wall. The protoplasm of the cell has two distinct portions—the *nucleus*, a dense, somewhat spherical body, and the *cytoplasm,* thinner and more watery in texture than the nucleus, which lines the inner surface of the wall in a thin layer and is bounded, without and within, by a very delicate membrane. (The *plastids*, small bodies somewhat denser than the cytoplasm and embedded in it, perform special functions, such as manufacturing food, building up starch grains, or producing colors.) The central portion of the root hair, or cell, is occupied by a sap cavity, or *vacuole*, is filled with water in which various substances are dissolved, and is surrounded externally by a layer of cytoplasm.

Absorption of Water. The cytoplasm and its membranes within the root hairs act as a semipermeable membrane or membranes, and the water is absorbed by *osmosis*. The root hairs contain sap that is ordinarily more concentrated than the soil solution. As a result the water from the soil passes through the cytoplasm and its membranes into the root hairs and continues its course as long as the difference in concentration is maintained. So long as the soil solution is less concentrated than the cell sap, the movement of the water is inward. If the soil solution becomes more concentrated, as sometimes happens in alkali soils, the movement of the water is from the root hairs into the soil solution, and *plasmolysis* results. In plasmolysis the cytoplasm is pulled away from the cell walls, the cells collapse, and as a result the plant may wilt. If the plasmolysis is extensive and long continued, it may cause the death of the plant.

Absorption of Nutrients. The nutrients are absorbed by the root hairs independently of absorption of water. It is necessary, however, that the nutrients be in solution and that sufficient water be present to allow the dissolved nutrients to diffuse. The nutrients are absorbed by the process of diffusion. Before being absorbed the nutrient compounds are usually ionized into their component ions, and there is absorption of ions. The dissolved substance is termed the "solute," and the water in which the solutes are dissolved is called the "solvent." A solution may contain several kinds of solutes in a common solvent. *The solutes tend to become equally diffused in the solvent or solution.* If two solutions that have a common solvent and different solutes, or the same solutes in unequal proportions, are brought together, being separated only by a semipermeable membrane, the solutes tend to pass through the membrane and reach an equilibrium. In the case of absorption of the nutrients from the soil, after the compounds have been ionized, there is a passage

of ions from the soil solution through the cell walls of the root hairs into the cell sap solution until an equilibrium has been obtained. For example, in case potassium nitrate (KNO_3) is added to the soil, the compound dissolves and usually becomes ionized into K^+ and NO_3^- ions. The former are positive and known as "cations," and the latter are negative and called "anions." If the cell sap contains as many NO_3 ions per unit of volume as the soil solution, there is no transfer of these ions through the cytoplasm and its membranes. On the other hand, if there are fewer K ions in the cell sap than in the soil solution, the K ions tend to pass through the cytoplasm and its membranes until an equilibrium is reached.

Thus, the passage of water through the cytoplasm within the root hairs is independent of the passage of dissolved substances. In other words, the passage of water is from the solution of lower total concentration. In the case of nutrients there is a tendency for the ions of the particular nutrient compounds to reach an equilibrium, regardless of the total concentration of the two solutions.

The Leaf and Its Functions. The vegetative portion of the plant naturally falls into two divisions—the root system and the stem and leaves. The former is situated in the soil and is mainly concerned with the absorption of water and certain nutrients from it. The stem and leaves, which taken together constitute the *shoot,* and which are produced above ground, are concerned primarily with the manufacture of food from the raw materials secured from soil and air. The leaf is physiologically the more important organ.

Structure of the Leaf. In order to understand clearly the function of the leaf it is necessary to have a knowledge of its structure.

Externally, a typical leaf consists of a green, broad, flat, thin portion, the *blade,* which contains a system of ribs, or *veins,* of stouter texture than the rest of the tissue. The blade is the seat of the important activities of the leaf and is sometimes attached directly to the stem but is usually attached by means of a leafstalk, or *petiole.*

Internally, the structure of the leaf shows much differentiation. A transverse section cut at right angles to the surface of the blade shows three important tissues: the *epidermis,* or protective covering; the *mesophyll,* constituting the major portion of the leaf substance; and the *veins,* each of which is a separate fibrovascular bundle and represents a final branch of the vascular system that runs through root and stem.

The epidermis covers the entire leaf surface and is one cell thick. The cells are usually thin walled and are filled with transparent cell sap. The epidermis is covered with a thin, waxy, waterproofing layer, the *cuticle.* It is usually thicker on the upper than on the lower surface of the leaf. The epidermis contains minute openings, the *stomata* (singu-

lar, stoma) through which an exchange of gases between the tissues of the leaf and the outside air may take place.

The mesophyll consists of tissue that is characteristically thin walled, soft, and green. The cytoplasm within its cells contains very small, roundish bodies, the *chloroplasts*, which are denser than the rest of the living substances and are green in color as the result of containing the green pigment *chlorophyll*, which is responsible for the characteristic green color of leaves. In typical leaves the portion of the mesophyll lying next to the upper epidermis is composed of elongated cells placed at right angles to the leaf surface. The cells are placed close together and are provided with chloroplasts in abundance. These cells are known as the *palisade layer* and in them the process of food manufacture, or photosynthesis, is most active. The lower portion of the mesophyll consists of a mass of cells so very irregular in shape that large air spaces occur between them, and a very loose, spongelike tissue, the *spongy layer*, is produced. The air spaces connect directly with the outside air through the stomata. In this portion of the mesophyll exchanges of gas take place, such as the absorption and excretion of both carbon dioxide and oxygen in the processes of photosynthesis and respiration and the evaporation of water in the process of transpiration.

The veins, or fibrovascular bundles, running through the blade are the channels by which the leaf tissues are kept in communication with the rest of the plant. The main veins are stout, but they break up into smaller ones. The fibrovascular bundles of the blade are continuous with those in the petiole, which in turn enter directly into the vascular system of the stem.

Photosynthesis. The food used in growth by green plants is manufactured in the leaves. The process is known as "photosynthesis." In the process carbon dioxide and water are combined. The method in which these substances unite is not known, but the formation of formaldehyde (CH_2O) is perhaps the first step. The first product that can be recognized is *glucose*, or *grape sugar*, $C_6H_{12}O_6$. Glucose is the fundamental carbohydrate and is the basis for all other foods, and from it are ultimately derived, through the action of enzymes and by various additions and chemical reactions, all the organic compounds of plants and animals. From the simple carbohydrates, proteins are produced by the addition of certain mineral nutrients. Photosynthesis is, therefore, a constructive process by which the food of the plant is manufactured from very simple inorganic materials, through the agency of chlorophyll and by energy derived from light. Oxygen is a by-product of the process.

The importance of photosynthesis to the life of plants should be appreciated, since from 85 to 90 per cent of the dry matter is made up of

organic materials manufactured in the leaves. The materials made by this process are used by the plant primarily as a source of energy and also as a means of building up their tissues.

Transpiration. Plants need a certain amount of water in carrying on their physiological processes. However, only a small percentage of the water that is absorbed by the root hairs and passes upward to the leaves is used in these processes. The remainder of the water evaporates from the cells of the spongy layer of the mesophyll, departing through the stomata as water vapor. The process by which the water evaporates from the tissues and passes into the air through the stomata is known as *transpiration.* The rate of transpiration depends upon several factors, some external and some internal. In considering the external factors it has been found that transpiration is increased under such conditions as those of high temperature, bright light, rapid air movement, and low humidity and decreased under conditions of the opposite nature. Certain internal changes in the leaf, such as opening and closing of the stomata and the variation in the concentration of the sap in the mesophyll cells, probably control to some degree the rate of transpiration.

The actual amount of water transpired depends upon the size of the plant, its leaf area, its transpiration rate, and the moisture of the soil. The amount of water transpired in relation to the amount of dry matter produced, which is known as the "transpiration ratio," or "water requirement," is of more importance than the total amount of water transpired. Briggs and Shantz[4] report results that show that when grown in rich soils plants transpire less water per unit of dry matter produced than when grown in poor soils. Montgomery[5] states that the amount of water lost by transpiration from the plant and by evaporation from the soil for each pound of dry matter produced by various plants is as follows: wheat, 225 to 650 pounds; barley, 262 to 774 pounds; oats, 402 to 665 pounds; corn, 233 to 400 pounds; and red clover, 249 to 453 pounds.

The question frequently arises as to the beneficial effect of transpiration in view of the large quantities of water lost by the plant in the process. The real significance of transpiration is not definitely known and is probably a necessary evil rather than an advantage. It certainly should not be stated that it is primarily beneficial.

The Stem and Its Functions. The root absorbs water and nutrients from the soil; the manufacture of food is carried on in the leaf. These organs are the primary ones of the vegetative system of the plant. A third member, the *stem,* connects these two. Its functions are secondary to those of the root and the leaf, but nevertheless they are important. The stem serves to place the leaves in a favorable position for photosynthesis and provides a means for transportation between leaf and root.

The stem also frequently serves as a storage organ and may be variously modified for other special functions.

Tillers. Frequently we find more than one branch developing from the primary stem of cereal plants. These are known as "tillers," and the number will depend on conditions. The conditions favoring growth, such as rich soil, abundant moisture, and the proper temperature, usually also favor the development of tillers. It has been found that thick planting decreases the production of tillers, while thin planting favors tillering.

Culms. The stems of grasses are known as "culms," and they are generally hollow except at the nodes. This is true of wheat, oats, rye, and barley, with the exception of some of the wheats, such as the spelts, which are partly or entirely filled with pith. The culm of the corn plant, popularly called the "stalk," is filled with pith. The leaves are alternate, two ranked, and parallel veined, as is common to all grasses.

Plant Foods. In the discussion of plant physiology the word "food" is frequently used with different meanings. As used here and by plant physiologists generally, *food* refers to any material that furnishes a supply of available energy to an organism or contributes materially to the upbuilding of its tissues. The three main classes of food are carbohydrates, fats, and proteins, and they are manufactured within green plants. Other materials taken up by the plant and used in its body, but which are neither important tissue builders nor energy producers, such as the essential mineral salts, may be called "nutrients."

Food Storage. As the organic compounds are formed in the leaves, they continually move to other parts of the plant. The sugar formed in the leaf is transferred into another carbohydrate, *starch*, but mainly after it has been translocated from the leaf. Neither sugar nor starch accumulates in very large quantities in the leaf blade. Food not used directly by the plant is stored by it for future use, chiefly in reproduction.

While the organic compounds are being translocated they are in a soluble condition, and after translocation takes place they become the relatively insoluble carbohydrates, fats, and proteins with which we are familiar as stored plant foods. In the ordinary field crops the food is stored chiefly in the reproductive parts.

Before compounds, which are comparatively insoluble, can be translocated or absorbed, they must be changed to a more soluble form. This change is brought about largely by enzyme action, and it is this process of converting an insoluble food into soluble form that is known as "digestion." After a food is digested, it must enter the protoplasm of the cell and become a part of the living substance—a process known as "assimilation."

Respiration. Respiration, unlike photosynthesis, which is limited to certain cells in the leaves, takes place in every living cell. Photosynthesis is a constructive process by which food is produced, whereas respiration is a destructive process by which food is destroyed, with a consequent release of energy, intake of oxygen, and outgo of carbon dioxide and water.

Energy Relations. The activities that are always taking place in a living cell require the expenditure of energy. In order to supply this energy, food is necessary. In the process of photosynthesis the active or *kinetic* energy of sunlight is transformed into stored or *potential* energy in food. This potential energy, under favorable conditions, may be converted again into kinetic form by respiration.

Respiration and Life. Respiration is believed to be a necessary accompaniment of life itself, as the living protoplasm is always active and is thus always expending energy. The release of energy that is characteristic of respiration is usually accompanied by the intake of oxygen and the liberation of carbon dioxide and water in case of higher plants. In some of the lowest plant forms, respiration may take place without the presence of free oxygen.

The respiration that takes place in the presence of oxygen is essentially an oxidation process. This is assisted by oxidizing enzymes or *oxidases* that occur in every living cell. A comparison of the chemical equations for photosynthesis and for ordinary respiration shows that they are exactly opposite. Photosynthesis adds carbon dioxide to water and produces sugar and oxygen. Respiration adds oxygen to sugar and produces carbon dioxide and water. In the former, kinetic energy becomes stored energy, and in the latter the reverse process occurs.

Comparison between Photosynthesis and Respiration in the Presence of Oxygen. The following comparison between these two processes may be made:

Photosynthesis	Respiration
Stores energy	Releases energy
Absorbs carbon dioxide	Liberates carbon dioxide
Liberates oxygen	Absorbs oxygen
Takes place only in green plants	Takes place in all plants and animals
Takes place only in chlorophyll-bearing cells	Takes place in all living cells
Constructs food	Destroys food
Increases weight	Decreases weight

Reproduction. Reproduction is the process by which the plant produces its offspring. There are two kinds of reproduction: (1) *asexual* or *vegetative* reproduction, in which portions of the body of the parent become detached from it and are set apart as new individuals, as in the

strawberry or the potato; and (2) *sexual* reproduction, where there is a union between two specialized reproductive cells, from which union a new individual arises. Most of the field crops are reproduced from seeds as a result of sexual reproduction. The new individual begins, not when germination of the seed takes place, but at fertilization, when one of the male nuclei from the pollen tube unites with the egg-cell nucleus in the ovule. The fertilized egg develops into the embryo or miniature plant, and in the case of cereals, the endosperm nucleus, which is fertilized by a second male nucleus, develops into the reserve food tissue or endosperm. Embryo and endosperm, surrounded by the seed coat, constitute the seed. In grains belonging to the grass family, the fruit has but a single seed, which is closely surrounded by the remains of the ovary wall, or *pericarp*.

The organs concerned in reproduction are the pistil and the stamens. The *pistil* is the female organ and is composed typically of (1) the ovary, which forms the base of the pistil and contains the ovules; (2) the style, a more or less elongated portion of the pistil; and (3) the stigma, or the portion of the pistil that receives the pollen grains. The *stamens* are the male organs of the plant. Each stamen is made up of (1) an anther, which contains the pollen grains and is usually borne on or near the apex of (2) a filament, which is a small threadlike stalk.

When the time arrives for reproduction, the anthers open and release the pollen grains, and these find lodgment in many instances on receptive stigmas. When pollination is thus accomplished, the pollen grain germinates, and the pollen tube penetrates into the stigma and down the style into the ovary. Here fertilization takes place by the union of two specialized sexual cells, or gametes, to form a single cell, the fertilized egg, from which a new individual develops.

Pollination and Fertilization. The transfer of the pollen to the stigma is known as "pollination." It is only a step toward the union of male and female gametes, which is known as "fertilization." A plant is said to be *self-fertilized* when the male and female gametes are borne by the same plant and *cross-fertilized* when one gamete is borne by one plant and the other gamete by a different plant. Wheat, oats, and barley are naturally self-fertilized, whereas corn and rye are usually cross-fertilized.

Inflorescence. The inflorescence of the cereals is usually terminal on the plant, as in the case of wheat, rye, barley, oats, and the male inflorescence of corn. The type of inflorescence is somewhat variable. In oats it is a loose panicle; in wheat, barley, and rye it is a spikelike panicle, which is more often called a "spike"; and in corn the pistillate inflorescence, which is borne on a lateral branch, is a thickened spike.

The inflorescence consists of a central stem, known as the "rachis,"

which is jointed. Branches, called "rachillas," arise from the joints and bear one or more flowers. The rachilla together with the flowers is called a "spikelet." Each spikelet is enclosed by two chaffy glumes and bears one or more flowers. As a rule, one or more seeds are produced.

Flowers. The grass floret consists of one fertile or flowering glume, the lemma, often bearing an awn from the back or apex, and the palea; one ovary, at the base of which are two lodicules; and three stamens. The reproductive organs of the individual complete flower consist of an ovary bearing a style and two stigmas. The flower also has three stamens surrounding the pistil, each consisting of a slender stalk or filament and a versatile, terminal, two-celled anther in which the pollen is produced.

With the exception of corn, the flowers of cereals correspond to the above description. In corn the stamens and pistils are borne in separate flowers on the same plant, as corn is a monoecious plant.

Structure of Cereal Seeds. In the case of oats and barley the grain is, with the exception of certain hull-less types, enclosed in the flowering glume and palea. The latter parts are called the "hull." The grains of other cereals, with the exception of some wheats, such as spelt, emmer, and einkorn, are removed from the hull in threshing.

The proportion by weight of hull to grain varies greatly, but in the case of oats the average is approximately 30 per cent hull and 70 per cent grain. The hull in the case of barley varies from 14 to 25 per cent, but the average is about 15 per cent.

The four parts of a cereal grain are (1) the protective covering, which consists of the seed coat proper or testa, and the pericarp or matured wall of the ovary; (2) aleurone layer; (3) endosperm; and (4) germ. The proportions of these parts will vary in different cereal grains. According to Hopkins, Smith, and East[6] the protective covering, including the tip cap, constitutes about 7.5 per cent of the whole kernel of corn; the aleurone layer, 8 to 14 per cent; the endosperm, about 70 per cent; and the germ, about 11 per cent. Ingersoll and Bessey[7] state that the protective covering of the wheat kernel constitutes about 5 per cent; the aleurone layer, 3 to 4 per cent; the endosperm, 82 to 86 per cent; and the germ, about 6 per cent.

Composition of Cereals. The composition of the seeds of a cereal differs according to variety. The "hard wheats" frequently have 13 to 16 per cent protein, whereas the "soft wheats" often contain 8 to 11 per cent. In the case of barleys the percentage of protein frequently ranges from 8 per cent for the soft barleys to 15 per cent for the hard barleys. In corn grains that have both hard and soft endosperm, the former is higher in protein. Hopkins and others[6] report that the hard endosperm

contains about 10 per cent protein and the soft 5 to 8 per cent. However, the differences found to exist between the hard and soft wheats and barleys are not found in hard and soft corns.

The composition of the cereal grains is shown in Table 1, taken from Chamberlain.[8]

TABLE 1.—TOTAL NUTRIENTS IN CEREALS, POUNDS PER HUNDRED ON WATER-FREE BASIS

Grain	Protein, lb.	Fat, lb.	Crude fiber, lb.	Carbo-hydrates, lb.
Oats	13.76	4.33	12.20	66.39
Wheat	14.20	2.36	2.78	78.72
Rye	13.44	1.83	2.30	80.24
Barley	13.39	1.87	5.64	76.05
Corn	9.91	4.40	2.21	81.96

Ratio of Grain to Straw. The proportion of grain to straw is not constant in cereals. The ratio will vary with such factors as the variety, thickness of planting, and productivity of the soil. However, as a rule, barley produces 1 pound of grain to 1 of straw; wheat, 1 of grain to 1½ of straw; oats, 1 of grain to 2 of straw; rye, 1 of grain to 2 of straw; and corn, 1 of grain to 1 of stover.

Vernalization. The influence of environmental factors during the germination phase of growth on the later development and fruiting of the plant has been designated "vernalization" (McKee[9]). It also is referred to under the term "iarovization," or "yarovization."

The economic objective of vernalization is the shortening of the vegetative period and the increasing yields of both seed and forage. The hypothesis of Lysenko,[10] who has been the chief proponent of the application of this principle, may be stated as follows: "The conditioning for sexual reproduction and vegetative growth in a plant may occur in the seed when the embryo has started development but has not yet broken the seed coat (or scarcely has done so), if proper environmental conditions are provided the seed at this time."

Thus vernalization is practically a seed treatment that influences the plant in its later stages of development. The seed is started into growth by the application of a limited amount of moisture and then subjected to other controlled factors: temperature, light, darkness, and time. The growth of the seed is arrested or controlled by limiting the amount of moisture, and in the case of seed treated at low temperature the cold is a limiting growth factor.

In the case of winter wheat and other so-called "winter annuals," the vernalization process consists of adding water to the seed in an amount that will scarcely or just bring the seed into visible germination. This will require a 1- to 2-day period with the temperature of the processing chamber kept at 10 to 12°C. The seed is then transferred to a temperature of 3 to 5°C., the moisture maintained by addition of water when necessary, and the seed frequently stirred. The time required in the cool room will vary, depending upon the temperature and variety of seed, but from 35 to 45 days is average.

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Topics for Discussion

1. Is the intake of plant food by plants voluntary or involuntary?

2. If all other conditions are equal will large seed produce more than small seed? Why?

3. Is transpiration a necessary function of plants or a provision for the removal of excess products?

4. From what source is the greater part of the dry weight of all plants obtained?

5. Do roots search for plant food in the soil?

CHAPTER VI

PLANT IMPROVEMENT

The opportunity to make a profit from plant improvement is very great. The acre yields of the various crops of the country are generally low. One of the best ways, under the control of the farmer, of increasing the yields of crops is the use of better seeds and plants.

Why Plant Improvement Is Profitable. Since the use of improved seeds and plants usually results in increased yields per acre, there is a decrease in unit cost of production with more profit to the producer and less cost to the consumer, other things being equal. The producer of improved plants or seeds may profit in two ways: (1) He may sell the products at a comparatively high price; and (2) he may increase his crop yields by using better plants and seeds.

Relative to the returns secured from crops the cost of seed is small, usually less than 10 per cent.

Pure-line Theory. The theory as developed by Johannsen conveys the idea that a variety is made up of a number of elementary species that can be separated out by pedigree methods. Selection isolates the elementary species from a mixed population or variety, but further selection within the isolated species is without effect, unless some heritable variation occurs. Therefore, the pure line conveys the idea of a group of plants all of which have the same constitution and will breed alike. A *pure line*, then, may be defined as the progeny of a single self-fertilized homozygous individual. Thus, the plants of a pure line must be self-fertilized and must breed true; *i.e.*, they must be homozygous.

Another definition is that a pure line includes the descendants of one or more individuals of like germinal constitution that have undergone no germinal change (Hayes and Immer[1]).

Why Plant Improvement Is Possible. That "like begets like" is true in large degree, but there are some exceptions. It is well known that no two plants are exactly alike; differences or variations are found everywhere. In a single variety of wheat are to be found plants that differ greatly. The difference may be in height, yield, color of seeds, or some other characteristic. In a single corn variety are to be found plants differing in yielding ability, time of maturity, color of stalk, etc. In timothy some of the plants have a tendency to spread, some to grow

erect, some are very leafy, and some are very resistant to disease. In fact, in no variety of any crop does variation seem to be absent. Variations are so widespread and our knowledge of them so meager that Darwin once said: "Our ignorance of variation is profound." In fact, variation is at once the hope and despair of the plant breeder. It allows the breeder to make advances, but at the same time constant attention is necessary in order to prevent an unfavorable variation from overcoming the good that has been accomplished. Thus, because of variation, plant improvement is possible by the selection, for foundation stock, of individuals that most nearly approach the type desired.

Modes of Reproduction. Field crops may be divided into four classes, based upon their mode of reproduction or propagation. These classes are as follows: (1) crops that are normally self-fertilized, such as wheat, oats, barley, beans, and vetches; (2) crops that are often cross-fertilized, such as corn, rye, grasses, alfalfa, and root crops; (3) crops that are obligatorily cross-pollinated, such as red clover, sunflower, hemp, and hops; and (4) crops that are propagated vegetatively, such as potatoes and sugar cane.

Plants that are normally self-fertilized may sometimes be cross-pollinated, as in the case of wheat. Leighty and Hutcheson[2] found that 40.97 per cent of cross-pollination takes place when wheat flowers were emasculated and left unprotected.

Plants often cross-pollinated may at times be self-pollinated and produce fertile seeds. However, self-fertilization in the case of cross-pollinated plants sometimes results in decreased yield and vigor. In the case of sunflowers, the self-fertilized seeds are sterile, whereas the cross-fertilized seeds are fertile. This fact makes the improvement of sunflowers more difficult.

METHODS OF BREEDING

In general there are two methods of breeding: (1) selection and (2) hybridization, followed either by direct utilization or by selection and fixation of new strains or varieties. In using these methods one should have a definite aim in mind. As a rule it is better to practice selection and isolate the best strains. If the desired individuals are not secured in this way, then individuals having certain desirable characteristics should be hybridized with the hope of combining in one individual the desirable characteristics of the parents.

The strains developed should be better than the best of the commercial sorts already developed. Therefore, before starting any breeding work, the breeder should make a careful survey of the varieties that already exist.

Selection. This method of breeding tends to increase the proportion of individuals belonging to a particular genotype in a population, *i.e.*, to those that breed alike. Selection is valuable, since practically all varieties are made up of strains that differ in certain characteristics. The object of this method of breeding is to isolate the better strains or elementary species from the variety. An *elementary species* may be defined as a small group within a botanical or horticultural variety. There are three kinds of selection: mass, pedigree, and clonal.

Mass Selection. By mass selection we mean the selection of the best individuals and the grouping or mixing together of their seeds. The seeds are planted en masse without any attempt to keep separate the progeny of each individual plant. This method is simpler than the pedigree system, but it takes a longer time to accomplish the same result. In mass selection the poor strains are likely to be carried along with the good ones, but these poorer groups are slowly eliminated. In pedigree selection only the best strains are continued in the tests, the poorer strains being early eliminated. It is evident, therefore, that in mass selection a limit is gradually approached, and this limit is that of the best strain or genotype in the population or variety. However, this limit is never absolutely reached because of the poorer strains present. In case of pedigree selection the best strains are isolated at once.

For a number of years mass selection has been practiced with good results. This method was used by Andre Leveque de Vilmorin in his selection of sugar beets for high sugar content. Rimpau used this method in making selections of rye and wheat and developed the Schlanstedt variety of rye in this way. This method has also been used with cotton and corn.

A noteworthy instance of plant improvement through mass selection is Grimm alfalfa. Another example is Buffalo alfalfa (Grandfield[3]).

Pedigree Selection. In pedigree selection, individuals are selected, and the seeds are planted in pedigree rows in such a manner as to keep the progeny of each parent separate. In this way not only the form but the performance of each individual selected is known, the poorer individuals can be eliminated, and the better ones carried into further trials.

The use of pedigree selection in case of self- or close-bred plants allows the breeder to make a rapid segregation of the elementary species or pure lines from a mixed population. This method has been used with cereals for a number of years. In the early part of the nineteenth century Le Conteur practiced pedigree selection. He introduced into commerce in 1830 the "Talavera de Bellevue" wheat. The same method was used about this time by Shirreff and by Hallet in the improvement of cereals. In America the method was first used by Hays in the improve-

ment of small grains at the Minnesota Experiment Station. Hays devised what is known as the "centgener" method of grain breeding, which, in brief, is the planting of 100 grains from each selected plant in trial plats. The more promising plants were selected from the best centgener plats, planted by the centgener method in succeeding years, and the process repeated from year to year.

The pedigree selection method is now widely used in the United States in the improvement of crops, and some very valuable results have been obtained. It is applicable not only to self-fertilized plants such as wheat and oats, but to the cross-fertilized plants such as corn.

Ear-to-row Selection. This is a form of pedigree selection formerly followed to a great extent in the improvement of corn. It consists in comparing the relative productivity of different ears of corn when planted side by side. Only a portion of each ear is planted; the remainder or remnant is saved until harvest time. At harvest time the yield of each row is obtained and compared with the yield of the check rows. Seed is not obtained from the highest yielding rows, since it may be crossed with pollen from low-yielding rows, but the remnants of several of the ears that were high yielding in the test are planted the next year in a breeding plat. Therefore, the ear-to-row selection serves to determine the high-yielding ears and not to produce seed corn.

Head-to-row Selection. This test is used in the pedigree selection of such crops as wheat and oats. In carrying out this test, a number of heads, say 50 to 1,000, are selected from as many different plants. These heads are usually selected from the general field. The yielding ability of the different heads is determined by planting in short rows. The rows for wheat are usually about 2.5 feet long and for oats about 5 feet long. Usually about 25 to 30 seeds of wheat or 40 to 60 seeds of oats are planted to each row. Every tenth row is seeded to some high-yielding standard variety with which to compare the head selections. A rigid selection of the strains grown in the head-to-row test results in the discarding of about 75 per cent during the first year. Each row saved is harvested and threshed separately. Such characteristics as stiffness of straw, maturity, yield, and disease resistance are taken into consideration. The second year the seeds from the best head rows are planted in the so-called "rod rows," a definite amount being seeded to each row and the approved rate of seeding being used for the particular grain. Every tenth row is planted with some standard variety, as in the case of the head rows. Usually two or three rod rows are seeded from each head row saved from the preceding year. The rows are harvested and threshed separately and the yields obtained. In the third year the seeds from the best rod rows are planted in rod rows replicated nine times, with every tenth row a check. The 10 rows from each rod row of the preceding

year may be harvested and threshed together or separately as seems most advisable. The yielding ability and other qualities of the various rod rows are studied. The procedure of the third year should be conducted for at least 3 years longer. If any selections are obtained superior to the check variety, they are carried to the multiplying plat to secure a supply of seed for field planting. The head-to-row test with wheat, oats, and barley is less difficult to conduct than the ear-to-row test with corn, since the former are self-fertilized. Therefore, with a crop like wheat no precaution is necessary to prevent cross-pollination, as is the case with corn.

Many other specific methods of pedigree selection have been proposed by different workers, but the two methods described will illustrate that the application in detail of pedigree selection is not uniform for all plants.

A good example of a variety developed through pedigree selection is Blackhull wheat. It is a selection from Turkey wheat and in 1939 was grown in over 8 million acres, being second only to the parent variety (Clark and Quisenberry,[4] and Clark and Bayles[5]).

Clonal Selection. This type of selection is applied to plants propagated asexually. It consists in the selection of the clones from a mixed population or the selection and propagation of variations within clones. A *clone* or *clonal variety* may be defined as one propagated asexually, as by cuttings, bulbs, or grafts. The varieties of strawberries, apples, and potatoes are examples. Here the bud rather than the seed is the unit of selection. Clonal selection is widely used in potato and sugar-cane breeding, and the method is generally followed in improving some kinds of grasses.

Hybridization. This method of breeding tends to change the type altogether by the introduction of new factors. Through the recombination of factors, strains having desirable characters are often recovered. In addition to the recombination of factors hybridization often increases vigor, at least temporarily.

The individual resulting from crossing contains factors of both parents and is called a "hybrid." A *hybrid* group may be defined as the progeny resulting from a cross-fertilization of parents belonging to different strains, varieties, species, or genera. Many hybrids have proved to be valuable additions, and a number of specific instances might be cited. The behavior of many characters in hydridizing has been studied. Individuals have been studied in regard to stature, earliness, yield, vigor, resistance to drought, resistance to disease, winter hardiness, presence or absence of awns, etc. These characters have been found to act in certain definite ways. It is difficult to estimate the value of hybridization.

Not only does the hybrid differ in constitution from either parent, but it is usually more vigorous than either one. With the increased vigor

are often found resistance to disease, better adaptation to environment, greater vitality of seeds, hastening of the blooming period, and earlier maturity.

Among the many new varieties developed by hybridization are the Thatcher and Ceres wheats, Wong barley (Aberg and Wiebe[6]), Benton and Clinton oats (Caldwell and others[7]), Ogden soybeans (Henson[8]), and S.L. 4108 sugar beets (Carsner and Owen[9]).

Notable progress has been made in developing new varieties of corn by hybridization. Much emphasis is now being placed in the development of new varieties of alfalfa through crossing (Tysdal and others,[10] and Tysdal and Kiesselbach[11]).

About 15 per cent of alfalfa plants are self-sterile, though it is a relatively simple task to produce hybrid alfalfa seed on a commercial scale. Two self-sterile lines are allowed to cross and produce a single cross. Two single crosses are allowed to produce a double cross. According to Tysdal and Kiesselbach,[11] four predetermined clonal lines are involved in a commercial double cross. They are propagated as cuttings rather than by seed. Two crossing fields are required for producing the two single-cross parental stocks. In each of these fields the two needed clones are space planted, respectively, into alternating cultivated rows to bring about the maximum amount of hybridization. Seed of the two resultant single crosses is planted in alternating rows in a field to produce the double cross. The seed crop is harvested in composite and constitutes the commercial hybrid seed. The field may be continued for hybrid seed production so long as the stand remains satisfactory.

Backcrossing. Backcrossing consists in crossing a hybrid with one of its parents. It is produced when it is desired to supplant one or two undesirable characters in the hybrid with desirable characters of the parent (Harlan and Pope,[12] and Suneson and others[13]).

Principles Involved in Breeding Crops. The principles involved in breeding crops that are self-fertilized, cross-fertilized, or propagated asexually vary to some extent. The details of the methods will vary for the different crops within a group, but the principles involved for a particular group will hold for all plants within that group.

Self-fertilized Crops. In crops of this kind the pedigrees are either pure or rapidly becoming so. The principles involved in such crops are as follows: (1) A selection is made of types that are already present. (2) The initial selection is everything; nothing new is added to the strain after the first selection. (3) Tests are made of the different strains isolated to determine their relative value. (4) After the selection has been isolated, further selection within the strain is of no avail.

Cross-fertilized Crops. Corn will be used to illustrate the principles involved in breeding these crops. The principles are as follows: (1) Corn

is naturally cross-fertilized, owing to the existence of a large number of elementary species within any variety and their tendency to cross-pollination. The natural crossing of these species or any variety of corn is likely to produce a hybrid complex for many factors. (2) Selection accompanied by inbreeding results in a gradual reduction to a homozygous or pure condition, the same purpose being accomplished by isolation of strains. In this way elementary species are isolated. (3) Inbreeding, as a rule, has harmful effects in case of corn. (4) Cross-breeding usually increases the vigor of corn. Inbred strains when crossed give greater vigor than that which results from crossing the varieties before inbreeding. (5) The pure-line method cannot be practiced successfully with corn, since the homozygous forms are of little value commercially. (6) Any successful method of corn breeding must provide for the natural crossing of different elementary strains within the variety.

Asexually Propagated Crops. The principles involved are as follows: (1) In asexual propagation a portion of the body plasm is passed to the next generation. There is, therefore, a very close resemblance between offspring and parent. (2) Since no reduction division takes place, there is no chance of segregation or recombination of factors. Strains breed true even though they are actually hybrid. (3) Theoretically, selection within such a strain should yield no results, since all members of a strain are of the same genetic constitution—a vegetative pure line. (4) Variation within such a group may be of the following nature: (*a*) fluctuations that are not inherited but are capable of exerting a certain temporary influence through effect on nutrition; (*b*) environmental modifications that are of such a nature as to be more or less permanently impressed upon the body plasm; (*c*) bud mutation, *i.e.*, any variation having its origin in a single bud. If the bud mutation is wide, it will give rise to a new variety, but if it is slight it may give rise to a new elementary species, provided the mutation is of the right sort. (5) If selection within a variety that is propagated vegetatively is effective, one of the following changes has taken place: either (*a*) transmission of body modification or (*b*) occurrence of bud mutation or variation. (6) Selection within varieties propagated asexually has been found effective in many cases. A single branch of an orange tree may bear superior fruit, and the wood of the branch is valuable for propagating a new strain of the variety.

RELATIVE IMPORTANCE AND LIMITATIONS OF PLANT IMPROVEMENT

Importance. It is difficult to estimate the value resulting from the improvement of crops. The results obtained from hybridizing corn are particularly noteworthy. The acreage of corn harvested in 1944 was only 5 per cent greater than it was, on the average, during 1935–1939, but the yields per acre were increased 32 per cent. Johnson[14] estimates that

the use of hybrid seed added 400 million bushels to the 1944 corn crop. Marked increases in yields have also been secured from new varieties of wheat, oats, barley, sorghum, potatoes, alfalfa, sugar cane, and, in fact, of practically all crops. Any variety tests show great differences in yielding ability and other characteristics of the varieties used and show that in order to secure the largest yields the best plants must be used.

Limitations. Plant improvement, although necessary for maximum production of crops, has its limitations. Usually the degree of improvement secured is small; however, this is not always the case. It is to be remembered that, even though the degree is small, the amount is large in the aggregate. In order to secure material improvement of crop plants much time and painstaking labor are required. After improvement has been achieved, it is necessary to continue to use a certain amount of care in maintaining the new standard attained. It is often difficult to impress upon the farmer the value of continued selection, prevention of mixtures, treatment for diseases, and other precautions to maintain the highest quality. Too often valuable additions to agricultural plants are lost because of the careless attitude of the farmer and his failure to realize their importance.

In the head-to-row test with small grains, 6 or 7 years are required before the definite behavior of any one of the original individual selection is determined. When the behavior has once been determined, several additional years are required to secure sufficient seed for extensive planting. In hybridization work, numerous crosses are frequently made and a large amount of selection done before a desirable type is obtained.

When all the limitations are taken into consideration, plant improvement still remains a highly profitable undertaking for the organizations and individuals interested in such work. The truth of this statement is easily shown, for a single improved plant means a step forward to agriculture and a definite gain to the people as a whole. It is difficult to estimate the value of corn hybrids to the corn growers, Marquis wheat to the wheat growers of the West, early-maturing varieties of cotton to the cotton growers in the boll-weevil-infested areas, and Fulcaster wheat to the Eastern wheat producers.

Plant Improvement under Farm Conditions. Much valuable work has been done by farmers in the improvement of plants. The work of Riley in the development of Boone County White corn, of Reid with Reid's Yellow Dent corn, and of Leaming with the Leaming variety is well known. Many progressive farmers practice selection in the improvement of the field crops they grow.

Mass selection is a very practicable method for farmers to follow in improving field crops. This method may be easily followed and excellent results accomplished with wheat, oats, corn, barley, potatoes, and, in fact,

with practically all field crops. Many farmers grow hybrid corn on a commercial scale, individually and through local associations.

Many farmers practice roguing of their crops, *i.e.*, removing admixtures. This practice is especially valuable in the case of small-grain crops. Rye is often found mixed with wheat, vetch with oats and rye, and barley with oats. It is not unusual to see smooth wheat badly mixed with bearded varieties, and vice versa. All such admixtures should be removed. In addition, the best types of a variety should be propagated for planting in succeeding years. Better care of seed will go a long way in preventing varieties from "running out."

That farmers can maintain and improve the quality of their crops in many respects is evidenced by the results that have been accomplished by a few progressive groups in various sections of the country.

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Topics for Discussion

1. Should farmers keep pedigree records of all seed planted?

2. Is production of new plants by hybridization practicable for the average farm?

3. Should the average farmer attempt any crop seed improvement?

4. Would you expect any increase in yield by selecting for seed the largest heads and heaviest grains from a pure strain of wheat over a 10-year period?

CHAPTER VII

THE VALUE AND USE OF GOOD SEED

Of the factors in crop production under control of the farmer there is nothing of more importance than the choice of high-yielding adapted varieties. Even though all conditions for growth may be most favorable, the yield will not be so good if a poor variety is used.

THE VALUE OF GOOD VARIETIES

Requirements of a Good Variety. In the choice of the variety to be used the following qualifications should be taken into consideration:

1. Adaptability.
2. Yielding ability.
3. Purity.
4. Quality of product for market or feeding purposes.
5. Disease and insect resistance.

Adaptability. It is of first importance that the variety be adapted to the section in which it is to be grown. Even when highly advertised, a variety may be absolutely worthless under practically all conditions. On the other hand, a variety may be excellent under some conditions but inferior under other conditions. The fact that a variety yields well in one region is no guaranty that it will necessarily yield well in another region. The same variety, however, may do well in two widely separated regions. The choice of the right variety, therefore, requires careful study.

Red clover and alfalfa seed from most foreign countries is not generally adapted for agricultural use in the United States. Certain portions of such seed must be stained red or orange-red as a warning to growers. Many other instances of poor adaptability could be mentioned.

Adaptation to Soil. The lack of adaptation may be due to a soil or a climatic condition or to both. It is well known that some varieties do well on some soils but not on others. Cunningham and Wilson[1] report that in Kansas the earliest and smallest varieties of corn yield best on poor soils, whereas on the rich soils the large varieties produce the largest yields.

Adaptation to Climate. Climatic conditions greatly affect the choice of the variety. It seems that some varieties are adapted to certain climatic conditions and not to others.

The relative yield of varieties of corn has been found to vary with rainfall. In Kansas, Cunningham and Wilson[1] found that the early maturing varieties yielded better under conditions of limited soil moisture, whereas the later maturing varieties yielded highest when the moisture supply was plentiful.

According to Morse,[2] the Clay variety of cowpeas yielded 34.3 bushels per acre in Georgia and only 9.8 bushels in Arkansas. On the other hand, the New Era variety yielded 6.9 bushels in Georgia and 39.9 bushels in Arkansas.

Length of Growing Season. The length of the growing season has marked effect on yield. A corn that matures in 150 days will yield more than one that matures in 125 days, other things being equal. The growing period should be long enough for the corn to utilize the entire season favorable for its development.

Certain varieties of wheat escape rust damage because of their early maturity, notably Marquis. It yields well, and its grain has excellent milling and breadmaking qualities.

Yielding Ability. It has been shown that before maximum yields can be obtained a variety must be adapted to the section in which it is to be grown. There is a great variation in the yielding ability of different varieties when grown under the same conditions and given the same methods of culture. The yielding capacity of varieties can best be determined by the study of results of variety tests conducted by experiment stations. Since varieties are often adapted to rather limited areas, the results of tests conducted in a neighboring section are likely to be more reliable than those secured in some remote section.

Purity. A pure variety is usually more desirable than a mixed variety. However, in some instances it has been found that a mixture of varieties will yield more than the same varieties when grown alone.

Quality. The quality of the crop produced may be as important as the quantity produced, or more important. It is desirable to produce wheat with a high milling quality, oats with a low percentage of hull, corn with a high percentage of grain to stalk and with a high percentage of marketable grain, cotton with long fibers, peanuts with a low percentage of hull, and potatoes with the qualities necessary for cooking purposes. Varieties differ greatly in respect to quality.

Ability to Resist Disease and Insect Attack. In order to secure best yields, it is highly desirable that plants have the ability to resist disease and insect attacks. Varieties, however, vary greatly in their abilities to do so. Ranger alfalfa is resistant to bacterial wilt disease (Westover[3]). Certain strains of red clover are resistant to leaf-hopper attacks and

anthracnose. These characteristics are the main reasons for their superior yielding abilities.

Influence of Mixtures. Varieties are often said to "run out." This may be due to the fact that other varieties have "run in" or that the varieties have lost their identity through mechanical mixture or lack of selection. With all varieties of crops it is well to practice selection to maintain the standard of the variety. In numerous instances, varieties have become so badly mixed as to be no longer recognizable.

FIG. 7. Resistance to disease is often an important consideration in the choice of varieties. Mohawk oats, on the left, are very resistant to Helminthosporium blight; while Vicland, on the right, are very susceptible. (*Courtesy of Cooperative G. L. F.*)

Everyone who has lived on a farm has seen beardless wheat plants present in fields of bearded wheat, and vice versa. Some fields possess a large number of plants that mature before the main crop. In many bins of wheat are to be found white and red kernels. These mixtures are often due to mechanical mixing, especially through the use of custom threshing machines.

The presence of white and yellow grains of corn on the same ear is a well-known occurrence. This mixing of varieties is to be avoided, since it may cause a decrease in yield and deviation from the varietal type. Spring vetch seed is sometimes found mixed with the seed of winter vetch. The latter is very winter hardy, while the former is very susceptible to winterkilling. Therefore, when spring vetch is mixed with winter vetch seeds the amount of winterkilling is usually increased. It is never a

good plan to mix varieties unless the grower is sure of his methods. As a rule, a decrease in yield results, and the variety characteristics are lost.

THE VALUE OF GOOD SEED

The use of seeds of good quality is of great importance in crop production. Although this fact is well recognized by the more progressive farmers, far too many seeds of inferior quality are being used. A knowledge of the qualities that make for good seeds is, therefore, very desirable.

Qualities of Good Seeds. Not only must good seeds belong to a good variety but they must have (1) strong germination, (2) proper size and development, (3) uniformity, (4) freedom from seed-borne diseases, (5) freedom from noxious and other weeds, and (6) freedom from mixtures with other crop seed.

Germination. Seeds that fail to germinate are, of course, worthless, whereas those which will germinate but produce weak seedlings are almost worthless. In practically all legumes and in many other cultivated crops are found hard seeds that fail to germinate quickly under favorable conditions for germination. The hard-seed character develops in legume seed during the final stages of maturity and is thought to be due to a layer of cells situated near the inner surface of the seed coat, which is almost impermeable to water. Whitcomb[4] found that most of the hard seed in alfalfa germinated within 3 weeks after planting, whereas hard seed from sweet clover showed a germination of only 3.3 per cent after having been planted in the field 24 weeks. If full and immediate germination is desired, hard seeds are objectionable. However, in the case of certain seeds that are planted very early, an extended period of germination may be of value in reducing the risk of the entire crop's being killed by a late frost.

Germination tests may be used to determine the viability and percentage of hard seed present. These tests are simple and inexpensive and should be resorted to whenever there is any doubt about the viability of seed to be planted.

Size and Development. The size of seeds is usually largely determined by the amount of reserve food supply carried for the young plant; and it is important that seeds be large, plump, and well developed. If the seeds are small or shrunken, they may not contain enough stored food to give the plants a vigorous start. Plants grown from poorly developed seeds may thus be stunted in the early stages of growth and never recover sufficiently to produce normal plants.

Kiesselbach,[5] at the Nebraska station, has made a very thorough study under practical field conditions of the influence of size of small grain seed on yield. He compared hand-selected large and small seed, repre-

senting extreme grades of winter wheat, spring wheat, and oats. Small seed yielded 18 per cent less than large seed when spaced to permit maximum individual plant development. Small seed yielded 10 per cent less than large seed when equal numbers of seed were sown per acre at an optimum rate for the larger seed, and 5 per cent less when equal weights of seed were sown per acre at an optimum rate for the larger seed. Unselected seed yielded 4 per cent less than large seed when equal numbers were sown per acre and 1 per cent less when equal weights were sown.

Williams,[6] in Ohio, found very little difference in the yields of large and small grains of wheat as separated by the fanning mill, but with hand-selected seeds the average of a 6-year test showed a 48 per cent increase in favor of heavy seeds over light. He states: "As a result of both of these tests it seems to be apparent that heavy kernels may be expected to give larger yields of wheat than light kernels, if the differences in weight of kernels are large enough; certainly is this true in pure lines, and possibly in a mixed population." Biometric studies with wheat conducted by Love,[7] at Cornell University, also indicate a relation between size of seed and yield. He says: "From the data in hand and other data that have been obtained at this station, we are safe in stating that if large (heavy) seed of wheat (also oats) are used for planting, they will come from the tallest, heaviest yielding individuals. Then, if there is a tendency for the parent plant to reproduce its type, a large yield may be expected from the heaviest seed."

A few experimenters have reported a failure to obtain increased yields from the use of larger seeds, but the preponderance of evidence seems to be in favor of large seeds over small seeds.

Uniformity. If seeds consist partly of fully developed grains and partly of small, weak grains, some strong and some weak plants will probably be produced. The large plants will have a tendency to crowd out the smaller ones, and thus reduce the stand. The plants from the inferior seeds may be more subject to attacks of diseases and insects, and in most cases may mature later than the stronger seeds. In the case of certain large seeds, such as corn and beans, it is important that the seeds be of uniform size so that they may be evenly distributed with planters. For all these reasons it is desirable that seeds for planting be as uniform in size as possible. Large and small seeds from the same plant frequently carry the same hereditary characteristics and under ideal conditions may give similar results in yield. However, large seeds well stored with food produce more vigorous young plants than small seeds and under adverse conditions may be expected to produce better plants.

Freedom from Disease. It is a well-known fact that many of the most serious plant diseases are carried on the seeds. Among these may be

mentioned smuts of small grains, root rot in corn, and scab in potatoes. These diseases cause enormous annual loss to the farmers of the country, and no seed may be truthfully said to be good seed unless it is comparatively disease free.

Freedom from Mixtures with Other Crop Seed. Adulterated or mixed seeds are objectionable because they produce a product that usually brings a low price on the market and because they often carry seeds of noxious weeds that may become serious pests. The selling price of small grain is always reduced if it contains an appreciable amount of any other small grain. In sections where rye and wheat are both grown, rye is often found in seed wheat. Such seed wheat is undesirable, as it will produce a product that is low in milling quality and will bring a lower price than rye-free wheat. Mixed grain of other cereals also sells at a reduced price.

Freedom from Weeds. Some of the most objectionable farm weeds have been introduced in seed. Wild onion, quack grass, Canada thistle, knawel, wild mustard, wild carrot, and corn cockle have been widely disseminated in impure seed. From an economic standpoint, these weeds present a serious problem. Pieters[8] found that in one sample of seed that contained only one-fifth of 1 per cent of foreign seeds there were 990 weed seeds per pound. If such seeds were sown at the rate of 10 pounds to the acre, 9,900 weed seeds would be sown to the acre, or approximately enough to place one weed seed on every 5 square feet of the acre. This sample would ordinarily have been classified as good seed, and yet it carried enough weed seeds, if all of them were viable, to reduce seriously the quality of the crop.

Conditions That Affect Quality. The conditions that affect the quality of seeds are (1) method of production, (2) method of handling, and (3) method of storage.

Method of Production. In order to produce good seeds, sound, well-developed, disease-free, unadulterated foundation stock should be used. Such stock should be planted on good ground and given good cultivation. If noxious weeds appear they should be removed before the seed crop is harvested. To produce good seed on good ground requires care and discrimination. To produce good seed on poor land with careless methods of culture is very difficult. The benefits to be derived from good seed will more than pay for the extra care and labor necessary to produce them.

Method of Handling. Seeds for planting should be very carefully handled at harvest time and during the period that intervenes between harvest and final storage, and care should be taken not to harvest the crop until the seeds are mature. Immature seeds will usually lack plumpness and vigor. In the case of small grains, the shocks should be well

made and every precaution taken to prevent water from entering the shocks and stacks. After the seeds are threshed, they should be spread in a thin layer and stirred until thoroughly dry. Damp grain will heat in the bin, and heating reduces germination.

Precautions for handling grass and clover seeds are very similar to those for handling the small grains. The chief consideration is to see that the crop does not heat, either before or after threshing.

Method of Storage. The chief precaution to be observed in the storage of seeds is to see that the seeds are dry before storage and to keep them dry in storage. Duvel[9] has shown that seeds deteriorate very rapidly when stored in damp rooms, even if the seeds are thoroughly dry before storage. Seeds that are subject, while in storage, to the attacks of insects, such as weevils, should be treated before storing to destroy these insects and should be kept in tight bins or receptacles.

Profits from the Use of Good Seed. Conservative agronomists estimate the yields from the use of pure, well-developed, disease-free seed to be from 10 to 20 per cent greater than those from ordinary market seed. Seeds of the best quality obtainable seldom sell for more than twice the price of ordinary seeds. Assuming that the quantity of hybrid corn of the best quality for seeding an acre costs $1 and that ordinary seed for an acre costs only 25 cents, the increased cost of seeding will be 75 cents an acre. If the ordinary seeds produce 80 bushels to the acre and the good seeds increase the yield only 10 per cent, 8 bushels of corn will have been obtained for the investment of 75 cents. The increased yield of corn would, in such a case, cost less than 10 cents a bushel up to harvest time. Similar results could be shown for other kinds of seeds.

Money invested in good seeds is good insurance. Good seeds may be produced on the farm with a little extra care and expense or may be bought from certified seed associations. Since this is the case, it is false economy to introduce an additional hazard into farming by the use of seeds of doubtful value.

HOW TO SECURE GOOD SEEDS

Even when it is realized that good seeds are important and necessary to obtain large yields, it is not always easy to secure them. At the present time not enough seeds of high quality are produced to plant the acreage annually planted to crops; in fact the actual demand is greater than the supply. Therefore, a knowledge of practical means of securing a larger supply of better seeds is worth while.

Methods of Securing Good Seeds. Good seeds may be obtained by (1) selection and breeding on the farm and (2) purchase from reliable breeders and dealers.

Improvement of Seeds on the Farm. The question of plant improvement under farm conditions has been discussed in Chap. VI. It is doubtful whether any farmer can afford to neglect the improvement of home-grown seeds. It has been shown that variations take place in all directions and that there are retrogressive as well as progressive variations. If no attempt is made to select the best seeds for planting and if no care is taken to eliminate diseases and mixtures, the yields of most varieties soon become lower. The practice of buying seeds that can be produced at home is usually wasteful as it involves transportation charges and cost of containers as well as a profit for each dealer who handles the seeds. Then, too, if one is not sure of the locality in which the seeds were grown, nonacclimated seeds may be obtained.

Purchasing Seeds. Up to comparatively recent years it was practically impossible to buy seeds of guaranteed quality. In fact at the present time a large number of seed houses specifically state on the container in which the seeds are shipped that they do not guarantee the seeds sold. The following is a typical statement that accompanies each shipment of seeds from certain seed houses: "We give no warranty, expressed or implied, as to description, quality, productiveness, or any other matter of any seeds, bulbs, or plants we send out, and will not be in any way responsible for the crop." Such statements, instead of implying a desire on the part of the seedsmen to evade responsibility, in many cases are necessary for their protection. Large seed houses cannot grow all the seeds they sell; and since they cannot buy under a guaranty, they cannot afford to sell under a guaranty. In recent years, however, a few private companies have been organized for the purpose of producing and selling guaranteed seeds, and many sections have crop improvement or seed associations made up of farmers who grow and sell seeds guaranteed under a rigid system of inspection. When seeds are to be purchased, it is usually best to buy from a company that gives a guaranty even if a much higher price has to be paid.

Seed Testing. Examples have already been given to illustrate the advantages of germination tests. If seeds are carefully cured and stored, they usually germinate well. However, a germination test is the only positive way of determining whether or not seeds may be expected to germinate. Such tests are always advisable before planting, but they are of particular importance when the method used in curing and storing the seeds is unknown. Germination tests not only show the total percentage of viable seed but show whether the germination is strong or weak and in some cases indicate the presence or absence of certain seeds that are the carriers of diseases.

Many types of germinators are used in testing seeds, but the principle

underlying all of them is simply to keep the seeds under proper temperature and moisture conditions for germination. Except in the case of corn, where the individual ear germination test is advised, a random composite sample is usually taken, and a given number of seeds are placed in the germinator. Proper moisture and temperature conditions are maintained until the seeds have been given sufficient time to germinate. The seeds are then removed from the germinator, and the amount of germination is determined. Weed seeds may be easily detected in large seeds, such as corn, peas, beans, and the small grains. However, in the case of small seeds, such as the clovers and grasses, a purity test is often of considerable importance. Many weed seeds are small and similar in appearance to useful seeds and can be detected only by careful examination. Since weeds present such a serious economic problem on farms, every precaution should be taken to sow grass and clover seeds that are comparatively weed free.

Seed Associations. For many years seeds have been produced and sold by organized groups of farmers. The object of the early seed associations was to grow and market seeds of a somewhat better quality than ordinary commercial kinds without any reference to the pedigree of the plants producing the seeds.

The modern seed associations have as their object the production of seeds of known ancestry as foundation stock that can be guaranteed to be pure, viable, and reasonably free from seed-borne diseases. Pedigree breeding has been practiced by breeders of animals for many generations. The modern seed associations attempt to apply to plants, in so far as it is practicable, the methods of registration and certification that have been used by animal breeders. The term "registered seed" as used by plant growers has practically the same meaning to them as the term "registered" has to producers of livestock. The chief difference is that practically any animal which is the progeny of registered ancestry may be registered, while certified seeds must be the progeny of registered ancestry and must also comply with a certain standard of perfection. The associations for producing such seeds are usually made up of farmers who cooperate with the agricultural experiment stations and use methods advocated by them. Owing to the fact that there is such a great variation in the adaptability of crops, it is not practicable to have large national associations handle the registration of seeds, as is done in the case of animals. However, there is a national crop-improvement association made up of representatives of the state seed associations. The duty of this association is to standardize the requirements for seed registration in the various states.

Many of the state crop-improvement associations and some Canadian

associations belong to the International Crop Improvement Association, which was organized in 1919 and which, among other considerations, attempts to coordinate and standardize seed-improvement work.

Advantages of Seed Associations. Although any grower may apply to his own farming operations the methods used by seed associations without regard to the association, yet affiliation with such associations brings certain advantages that are a great asset to growers. These, according to an undated report of the Canadian Seed Growers' Association, are

1. It enables the grower to keep in touch with his fellow worker and thus to profit by the successes and failures of the latter.
2. It keeps him in touch with the best thought of the times in all matters pertaining to crop raising.
3. It fixes approximate standards of registration for pure-bred seed.
4. It makes a careful study of the results obtained by the different members, as well as by professional investigators, and offers direction and guidance accordingly.
5. It keeps the records of all work done along these lines by members and issues certificates of registration.
6. It assists members as far as possible in the disposal of their surplus stock of pure-bred seed at a reasonable rate.
7. It gives publicity to the work of worthy growers who have succeeded in producing stock of real merit.

Production of Certified Seeds. The usual requirements for the production of certified seeds are (1) that the seeds be grown from certified seed stocks; (2) that the crops pass an inspection for mixtures, weeds, and diseases in the field; and (3) that the harvested crops attain the standard of perfection set by the association. Certified seed stocks may be obtained from members of the association who are already producing certified seeds and from experiment stations, or they may be produced by compliance with certain regulations and requirements of the association.

The field inspection is made by an agent of the association who has had sufficient training in agronomy, plant pathology, and botany to enable him to determine if the seeds as grown in the field are true to type and are free from noxious weeds and seed-borne diseases. After the seeds have been threshed, representative samples are taken and carefully analyzed. Determinations are made of weight per bushel, foreign material, germination, moisture content, purity, and percentage of large whole seeds. The field and final inspections taken together furnish complete and reliable information as to the quality, condition, and purity of the seeds. If the seeds meet the established standards in both inspections, they are certified and admitted to registration and may then be sold as

certified seeds or used as foundation stock for the production of certified seeds. The registered seed associations keep complete records showing by whom and in what year the seeds were produced. These records also show the locality in which the crop was grown and give a complete analysis of the seeds based on the field and bin inspections. A certificate of registration bearing all necessary information, including the registration number of the particular lot of seeds, is given to the grower. All seeds sold as certified seeds bear the association's stamp of approval and are shipped under a tag that carries the grower's name and a guaranty of purity and germination.

Seeds grown and sold under such regulations are far superior to ordinary commercial seeds. It is estimated that the use of certified seeds in Michigan has increased crop yields not less than 10 per cent. Since it costs more to produce certified seeds than it does to produce ordinary seeds, the certified seeds sell for more than uncertified stock. However, the extra cost of the seeds is more than compensated for in larger yields of better quality.

Seed Laws. Many states have seed laws designed to control the quality of the seeds sold within their borders. It is evident that the purpose of such laws is to raise the standard of seeds and to protect the citizens against the possibility of buying seeds of inferior quality. There is a considerable variation in these laws in the various states. In most states the laws do not forbid the sale of seeds of low quality but merely require that a statement of the germination and purity of the seeds accompany each package of seeds sold. In some cases the seed dealer is required to state on the shipping tag the kind and percentage of foreign seeds in the seeds sold; in other cases no seeds can be sold that contain more than a stated quantity of certain noxious weed seeds. These laws have done much to improve the quality of commercial seeds. However, when farmers buy seeds by mail order, they usually get no information concerning the quality of the seeds purchased until they read the accompanying statement of quality after the seeds have been received. Seed laws are greatly strengthened if dealers are required to furnish, with their price lists, statements of germination and quality.

The seed laws are frequently enforced by state departments organized for this purpose. These departments keep inspectors in the field who are authorized to draw samples of seeds wherever found. The samples are then analyzed, and, if they are being sold contrary to law, the dealer is subjected to the penalties of the law.

Most of the seed laws do not cover garden or field seeds sold in small packets. If such laws were extended to cover all seeds sold regardless of quantity, their usefulness would be greatly increased.

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Topics for Discussion

1. Which is more important in seed corn, good strains or good varieties? In wheat?

2. What are the most important reasons for seed deterioration on farms?

3. How would you estimate the value of a new variety?

4. List in order of importance the proper procedure in procuring good seed.

CHAPTER VIII

FERTILIZERS AND LIME

National welfare, particularly a healthy agricultural economy, depends on productive soils. Soils may be naturally fertile, or they may be naturally rather infertile and unproductive. Fertilizers and lime are often required to maintain the productivity of fertile soils and are extensively used to make relatively infertile soils profitable (Parker and others[1]).

FERTILIZERS

The use of fertilizer materials as a means of supplementing the natural food supplies of the soil is of considerable importance among the various factors involved in the economical production of crops as well as in the proper maintenance of soil fertility. Without certain elements, such as nitrogen, phosphorus, potassium, calcium, magnesium, and others, plants cannot live. With inadequate amounts of these elements plants are undernourished and fail to grow and produce normally. Undernourished plants, in turn, are likely to mean undernourished men and animals. It is to supply deficiencies in these essential elements that fertilizer materials must be added to the soil (Schreiner and others[2]).

Plant Nutrients. The fourteen essential elements for plant growth may be listed for convenience into the following groups:

A. Obtained from air and water.

1. *Carbon*, *hydrogen*, and *oxygen*. These elements account for over 90 per cent of the total weight of the plant. They are usually available in sufficient amounts to meet plant needs.

B. Obtained from the soil.

1. *Nitrogen*, *phosphoric acid*, and *potash*. These three elements are known as "primary plant foods" and are needed by plants in relatively large amounts and have long been recognized as those most likely to be deficient in soils.
2. *Calcium*, *sulfur*, and *magnesium*. These secondary plant foods are important to plants and are usually needed in relatively large amounts.
3. *Iron*, *manganese*, *copper*, *zinc*, and *boron*. These elements are usually designated as "minor plant foods." They are needed by the plants in only minute quantities but nevertheless are

absolutely essential to plant growth. When deficient in the soil, they should be applied in connection with the fertilizer program.

Other elements that are receiving attention in plant and animal physiology but of which very little is known at present are *iodine*, *arsenic*, *barium*, *cobalt*, *strontium*, *cesium*, *titanium*, *chromium*, *vanadium*, *aluminum*, and *silicon*.

The Functions of Nitrogen, Phosphoric Acid, and Potash. Since the great bulk of the fertilizers in this country consists of nitrogen, phosphoric acid, and potash, either alone or in combination, their functions in the plant will be briefly enumerated.

Nitrogen. Nitrogen increases growth and defers maturity. It produces a good leaf and stem development and gives to plants that luxuriant dark-green color which is so desirable in growing crops. An oversupply of nitrogen is indicated by a too great proportion of stem and leaf to fruit, and in small grains such an oversupply may cause a weakness of stem with resultant lodging and inferior grain. When a soil is poor in nitrogen, plants do not grow large and usually have poor color. The result of too much nitrogen is very similar to that of large supplies of water, whereas the result of too little nitrogen is very similar to that brought about by drought. No matter how much phosphoric acid and potash there may be in the soil, the crops can use only quantities in proportion to the growth of the plants, and the growth of the plants will be in proportion to the nitrogen in the soil.

Phosphoric Acid. Phosphoric acid hastens maturity of crops and aids in transferring substances from the stalk, leaves, and other growing parts to the seed, making the grains plump and full. It increases the proportion of grain to straw and also stimulates root development in young plants. An insufficiency of phosphoric acid is indicated by a too small proportion of grain to straw and by slow maturing of crops. According to Collings,[3] the presence of phosphoric acid in the plant has been found to influence cell division as well as the formation of fat and albumin. In its absence starch will not change to sugar. Phosphoric acid is seldom found in soils in sufficient quantities to injure plants. In some soils it is probably more often the limiting factor in crop production than any other plant nutrient.

Potash. Potash is essential to the formation of starch, sugar, and cellulose, and, where it is insufficient, plants do not mature well. It strengthens the stems, and the balancing effect that it seems to have on phosphoric acid and nitrogen causes better proportion of vegetative parts to fruiting parts. One of the most striking indications of an insufficiency

of potash is the early ripening or dying of the stems and leaves of plants while the seeds or fruit are still immature. Weak stems, when not caused by an overbalance of nitrogen, may indicate a lack of available potash. Root crops respond readily to applications of potash fertilizers and fail to do well when enough potash is not available.

Extent of the Fertilizer Industry. According to Mehring and others,[4] the total consumption of commercial fertilizers in the year ended June 30, 1944, was about 12,360,000 tons, containing 617,000 tons of nitrogen, 1,265,000 tons of available phosphoric acid, and 626,000 tons of potash. Mixed fertilizers, 8,500,000 tons, constituted 70 per cent of this total. The other 30 per cent included 1,600,000 tons of superphosphate, 800,000 tons of nitrate of soda, 196,000 tons of raw rock phosphate, 162,000 tons of ammonium nitrate, and lesser quantities of more than 40 other materials.

Only 262 different grades of mixed fertilizers were sold in the fiscal year 1943–1944 as compared with more than a thousand before 1939. The most popular grade is 2-12-6, which accounted for one-sixth of the total. The 5-10-5 grade is growing rapidly in popularity.[4]

In mixed fertilizers, ammonia supplied 72 per cent of the nitrogen, superphosphate 94 per cent of the phosphoric acid, and muriate of potash 80 per cent of the potash.[4]

The tonnage of fertilizers consumed in each region of the United States and the percentage of the total are shown in Table 2, on a calendar-year basis for certain years, beginning with 1910 (Mehring and others[4]).

Economy in the Use of Fertilizers. It is an undisputed fact that commercial fertilizers are profitable when properly used and in many sections are indispensable for economical crop production.

The most obvious and probably the most striking effect of using fertilizer is that it increases crop production. The yield data of a few crops from widely scattered areas are graphically presented by Parker and others[1] in Fig. 8.

Smalley and others[5] made a nation-wide survey in 1940 to determine from 48,000 farmers an expression of their opinion of the agricultural value of the fertilizers they used in 1939. The results of this survey are shown in Table 3.

The survey mentioned above also furnished data to show the average increases in yields produced by 1 ton of fertilizer on various crops. The results are presented in Table 4 (Smalley and Engle[6]).

Factors and Theories Relative to the Use of Fertilizer. The primary object in the use of fertilizer is to obtain a profit from the increase in yield of crops from the land on which the fertilizer is applied. There are a number of factors that have either a direct or an indirect influence upon

TABLE 2. TRENDS IN FERTILIZER CONSUMPTION, BY REGIONS, CALENDAR YEARS 1910–1945

Region	1910		1920		1930		1940		1944		1945	
	Consumption, 1,000 tons	Proportion of total, per cent	Consumption, 1,000 tons	Proportion of total, per cent	Consumption, 1,000 tons	Proportion of total, per cent	Consumption, 1,000 tons	Proportion of total, per cent	Consumption, 1,000 tons	Proportion of total, per cent	Consumption, 1,000 tons	Proportion of total, per cent
New England	208	3.82	351	4.89	372	4.53	339	4.11	460	3.82	500	3.79
Middle Atlantic	853	15.64	1,017	14.18	1,086	13.22	1,205	14.61	1,529	12.68	1,571	11.90
East North Central	339	6.22	672	9.36	788	9.60	912	11.06	1,770	14.69	2,082	15.77
West North Central	34	0.62	115	1.60	110	1.33	151	1.83	404	3.35	491	3.72
South Atlantic	3,146	57.70	3,999	55.73	3,857	46.97	3,501	42.44	4,692	38.92	5,038	38.16
South Central	828	15.19	942	13.13	1,812	22.07	1,825	22.12	2,585	21.44	2,814	21.31
Western	44	0.81	80	1.11	187	2.28	316	3.83	615	5.10	707	5.35
Continental United States	5,452	100.00	7,176	100.00	8,212	100.00	8,249	100.00	12,055	100.00	13,203	100.00

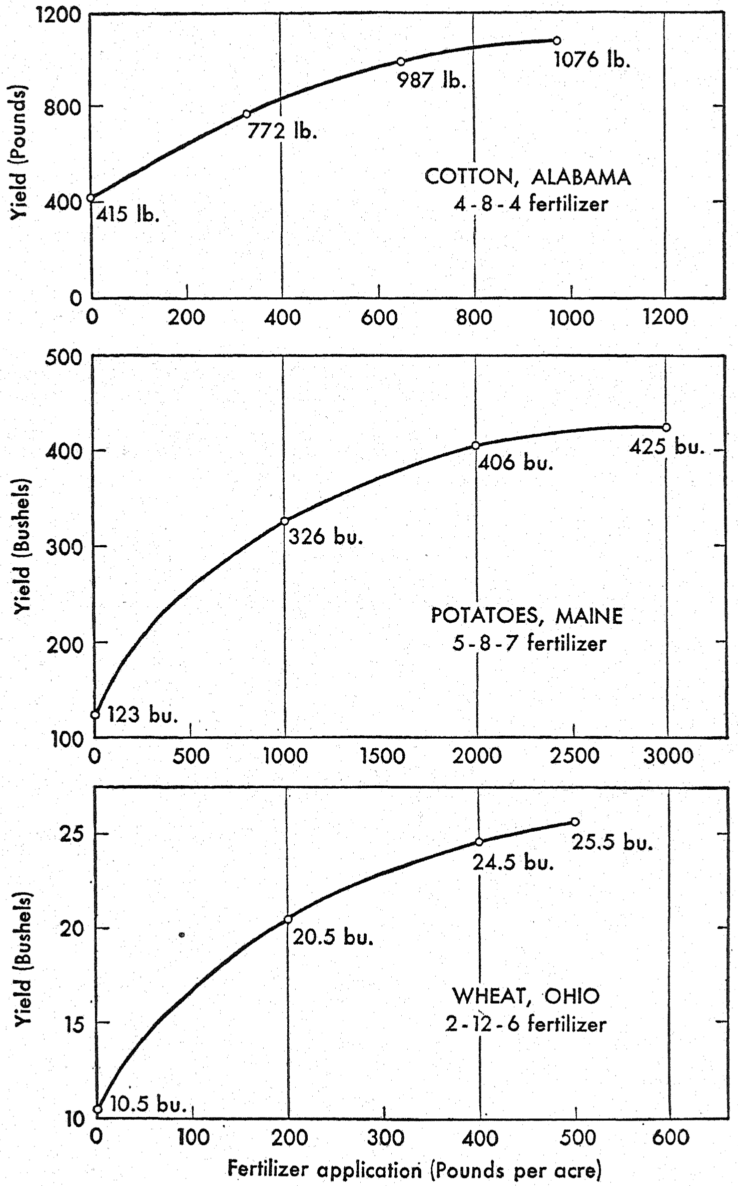

FIG. 8. Increase in yields of cotton, potatoes, and wheat as influenced by increases in fertilizer application. (*Parker and others.*[1])

the profits that may be obtained from the use of fertilizers. A few of the more important of these are (1) soil type; (2) weather conditions; (3) crop grown; (4) productivity of the soil; and (5) length of growing season.

TABLE 3. CROP RETURNS FROM THE USE OF COMMERCIAL FERTILIZER, BY CROPS

Crop	Value of crop produced by fertilizer	Tons of fertilizer used on crop	Estimated cost of fertilizer	Increase in value of crop for each dollar spent for fertilizer
Corn	$ 84,387,890	1,632,600	$ 40,672,300	$2.07
Cotton	171,709,646	1,501,800	38,424,600	4.47
Wheat	33,355,404	739,300	18,915,600	1.76
Potatoes	55,004,062	555,500	17,671,050	3.11
Fruits and vegetables	62,501,271	556,360	16,342,400	3.82
Tobacco	135,937,201	505,400	15,033,000	9.04
Citrus fruits	31,848,310	256,000	8,819,000	3.61
Hay and alfalfa	11,426,347	239,300	5,161,000	2.21
Oats	8,108,377	247,000	5,635,500	1.44
Sweet potatoes	19,613,563	133,000	3,545,150	5.53
Tomatoes	12,108,895	85,400	2,641,200	4.58
Peanuts	6,210,370	57,000	1,469,000	4.23
Miscellaneous	77,598,839	807,740	22,617,870	3.43
Total	$709,810,175	7,316,400	$196,947,670	$3.60

Soil Type. It is a well-known fact that soils differ widely both in their chemical composition and in their physical properties, both of which have a direct influence on the effects of any specific fertilizer application. For example, clay soils have the ability to retain certain fertilizer

TABLE 4. AVERAGE YIELD INCREASES PRODUCED BY 1 TON OF FERTILIZER

Crop	Yield Increase
Corn	125 bu.
Cotton	2 bales
Wheat	85 bu.
Oats	140 bu.
Tobacco	1,370 lb.
Potatoes	185 bu.
Sweet potatoes	285 bu.
Soybeans	50 bu.
Peanuts	200 bu.
Tomatoes	215 bu.
Snap beans	130 bu.
Apples	700 bu.
Milk	8,000 lb.
Beef	1,000 lb.

materials, whereas sandy soils are not very retentive of plant nutrients and are more subject to the bad effects of leaching. Obviously, the effects of the same amounts of fertilizer on these different soil types would be dissimilar even though the soils showed the same chemical content of plant nutrients. From a chemical standpoint, sands consisting largely of quartz are usually much lower in plant nutrients than clays that are made up of a number of minerals.

Weather Conditions. Weather conditions may affect the profits from fertilizers because the condition of the weather often becomes the limiting factor in plant growth. No amount of plant nutrients can increase crop yields if there is not sufficient moisture, nor can profits be made from the use of fertilizers when the growth of crops is limited by excessive moisture. Thus it is seen that if the weather is unfavorable, no profits may be obtained from the use of fertilizer.

Character of Crop. The financial result from the application of fertilizer is also influenced by the character of the crops grown. Most of our field crops remove a comparatively large amount of fertilizer constituents from the soil and as a rule possess a relatively low commercial value, although some remove comparatively small amounts of fertilizer constituents from the soil and have a relatively high commercial value. In the first group are included such crops as the cereals and forage crops, and in the second, vegetables and fruits. As a general rule, crops which have a high acre value give larger returns from the use of fertilizer than do crops of low acre value.

Productivity of the Soil. The profit obtained from the use of fertilizers is also greatly influenced by the natural productivity of the soil. An example may be seen in the fact that certain soils of the East that have been cropped for generations cannot be farmed profitably without fertilizers. Crops grown on such soil usually respond to the use of commercial fertilizers. However, some of the soils of the West that have been farmed less than a century do not give profitable returns from the use of fertilizers.

Length of Growing Season. The right proportions of nitrogen, phosphoric acid, and potash in the soil have a marked influence upon the time of maturity of the corn crop. Thus the addition of fertilizing materials to bring about the proper proportion of nutrients may hasten maturity and, with certain crops, thereby increase profits. In localities where seasons are short, fertilizers may be used to hasten maturity, even when they do not increase crop yields.

Systems of Fertilizing. Owing to the fact that there are so many factors that influence the results to be expected from the use of fertilizers, it is impracticable to attempt to give information concerning the

use of fertilizers that will apply equally well under all farming conditions. However, there have been a number of fertilizing methods or systems suggested, each of which possesses some merit.

A System Based upon the Influence of a Single Element. This system assumes that as far as fertilizing is concerned crops may be divided into three groups: (1) plants especially benefited by nitrogen, (2) plants especially benefited by phosphoric acid, and (3) plants especially benefited by potash. In this system it is asserted that nitrogen is the dominant ingredient for wheat, rye, barley, grass, and oats; phosphoric acid for turnips, corn, sorghum, and sugar cane; and potash for peas, beans, clover, flax, and potatoes. This system does not advocate the use of single elements only but requires that the dominant element for a certain group be the dominant ingredient of the fertilizer used for the crops of that group. In the case of soils of high productivity the specific element for the group may be used simply to force a maximum crop growth. Thus, specific fertilizing is arranged for the various rotations, the crop receiving that which is most useful. The chief objection to this system is that it cannot be depended upon to give results where the soil is in a low state of productivity.

A System Based upon the Necessity of an Abundant Supply of the Minerals. This system requires that the mineral elements, phosphoric acid and potash, which do not readily leach out of the soil, be maintained in an available form in amounts much greater than are required to meet the immediate needs of plants. Nitrogen, which is more readily lost from the soil, is to be applied in active forms, in such quantities, and at such times as will ensure maximum yields. This system is useful in building up unproductive soils quickly and in increasing the production of crops that give large financial returns to the acre.

A System Based on Chemical Analysis of Plants. This system is based on the theory that the different plants should be provided with nitrogen, phosphoric acid, and potash in the proportions in which they exist in plants, as shown by chemical analyses. It does not take into consideration the amount of plant nutrients already in the soil, or the difference in ability of different types of plants to secure their nutrition from the soil. The method may be applied to greenhouse work in growing market garden crops, but it is usually not economical for use in the production of ordinary field crops.

A System in Which Fertilizer Is Applied Only to the "Money Crop" in the Rotation. In this system the crop in the rotation that gives the largest money returns per acre receives a heavy application of fertilizer. The application is in excess of the immediate needs of the crop, and the other crops in the rotation use the residue left by the money crop. This

system is often used with such crops as potatoes and tobacco, which require, for best returns, an excessive amount of available plant nutrients in the soil. For example, a tobacco crop may receive an application of 2,000 pounds of a fertilizer carrying 3 per cent nitrogen, 9 per cent phosphoric acid, and 6 per cent potash. This quantity is considerably more than an ordinary crop of tobacco will use, and there is, therefore, a considerable residue left in the soil that may be used by the succeeding crops. This method possesses many valuable features and is, perhaps, as good as any other to use in field-crop production.

There are good features in all these systems, and it rests with the farmer to use that which in his judgment applies best to his conditions. These systems do not take into consideration differences between soils in their physical and chemical relations nor do they take cognizance of the benefits to be derived from such practices as green manuring and liming. Perhaps the best systems to be practiced are those which are recommended by the state experiment stations or which are being used successfully by neighboring farmers.

Fertilizer Placement. Investigational work on fertilizer placement was begun in 1931, and since that time new fertilizer-distributing machinery has been developed. Further attention has been given to the drilling properties of fertilizers, and a greater number of farmers have become interested in improved methods of fertilizer application.

Salter[7] states that applying fertilizer in the right place is fully as important as applying the right analysis or the right amount.

No single fertilizer pattern has been found superior with all crops and under all conditions, continues Salter.[7] Almost without exception, however, in the numerous comparisons that have been made, placing the fertilizer at the sides of the seed or plant has been most efficient. On the average, no other placement appears to be even a close second. Most damaging is placement directly in contact with the seed, although this placement is sometimes advantageous where the rate of application is low and plenty of rain falls soon after planting. Placement in bands directly over the seed is usually inferior, the fertilizer tending to wash down on the seed and injure it. Bands directly below the seed are little better if placed at shallow depths, the fertilizer tending to rise with the capillary water and cause trouble. Mixing the fertilizer in the row with the seed or under the seed is sometimes good but often not if the soil happens to remain fairly dry after planting. It is relatively poorer as the rate of application increases.

The general superiority of side-band placement is easily explained by the tendency of fertilizer salts to move up and down but only slightly in a horizontal direction. The seed lies in soil free of fertilizer, and both

young roots and shoots can develop without coming into contact with an excess of fertilizer salts. A narrow band of fertilizer-free soil at the side of the seed, between it and the fertilizer band, serves to prevent damage.

Quality More than Quantity. Up to this point our attention has been focused on the problem of preventing soil deficiencies from limiting crop yields. But the consumer is concerned more with quality than with acre yields of food crops, and he might well raise certain embarrassing questions, of which the following are examples (Bear[8]):

1. Would it be desirable for those who live in high-rainfall regions to use more food and feed from the semiarid regions and less from the areas nearer home?
2. Should the quality of the soil and its underlying rock be taken into consideration in choosing a location in which to bring up calves, colts, chicks, and children?
3. Does it make any difference to the consumer whether the apples, asparagus, cabbage, corn, onions, oranges, peppers, potatoes, turnips, tomatoes, snap beans, spinach, watermelons, and wheat that he eats were grown on good or poor soil?
4. Is it a matter of any moment to men and animals whether farmers in high-rainfall areas lime the land on which they grow their crops?
5. Are properly fertilized crops to be preferred over those grown on soils in a low state of fertility?

Extra Values in Some Soils. A great many isolated facts are known that, when pieced together, aid in answering some of these questions. Among these, the following typical examples are noteworthy:

1. The earliest civilizations reached their highest levels and greatest permanence on the unleached soils of semiarid areas.
2. Limestone valleys, the world over, are highly favored for livestock production.
3. The bluegrass region of Kentucky, famed for its fine horses, is located on soil having a very high phosphorus content.
4. The inhabitants of certain localities in Texas are seldom troubled with decaying teeth.
5. Notably fine physical specimens of mankind are found in the relatively dry Great Plains area of this country.

Mineral-deficient Areas Known. In contrast, there are many examples of impairment in the health of men and animals growing out of a lack of essential mineral elements in the foodstuffs, of which the following examples, chosen mostly from the United States, are illustrative:

1. The Great Lakes region has a high incidence of goiter, presumably by reason of the lack of iodine in the rocks, soils, and vegetation of that region.

2. Low-phosphorus soil areas have been found in Montana, Minnesota, and Michigan, where livestock is badly stunted, tending to have small bones and stiffened joints.

3. Deficiencies of cobalt have been reported from Florida, Texas, and New Hampshire, as a result of which animals suffer seriously from anemia.

4. Evidence indicating a lack of iron, copper, and managanese in the diet, of both children and livestock, has been noted in some of the poorer marginal-land areas of Florida.

5. Reports from Finland suggest that people located in regions of acid soils are more subject to tuberculosis than those living in high-lime areas.

LIME

The practice of applying lime to the soil is very old, probably extending back many years before the Christian Era. However, it did not receive much attention in the United States until the beginning of the twentieth century.

The total consumption of liming materials in the United States, according to Parker and others,[1] reached 7.9 million tons in 1938, 15.8 million tons in 1941, and 18.8 million tons in 1943. The great increase in the use of lime is further substantiated by the fact that in 1918 the annual consumption was about 1.2 million tons.

In 1943, Illinois used 3,773,000 tons of lime; Iowa, 2,173,200 tons; Ohio, 1,520,600 tons; Missouri, 1,483,000 tons; and Indiana 1,264,500 tons. These five states used 54 per cent of the total lime used in the United States during that year.

Lime Defined. The different forms of lime, from an agricultural standpoint, are the oxide, hydroxide, and carbonate of calcium or magnesium. Lime in any of its forms practically always carries magnesium as well as calcium, the latter usually predominating. Calcium sulfate or gypsum is sometimes classified as a form of lime, but, since its functions in the soil are somewhat different from those of the first-mentioned group of calcium and magnesium salts, it will not be considered here. Lime is usually called a soil "amendment" rather than a fertilizer, as it does not carry nitrogen, phosphoric acid, or potash. Lime frequently makes it possible to use more commercial fertilizers with profit.

Commercial Forms of Lime. The commonly used commercial forms of lime are (1) burnt lime, (2) water-slaked lime, commonly called "hydrated" lime, (3) ground limestone, (4) ground shells, and (5) marls. All these materials are useful for agricultural purposes but vary to a certain extent in effectiveness. Burnt lime, *i.e.*, calcium oxide and magnesium oxide, is the most concentrated form of lime. Burnt lime is changed into the carbonate form very rapidly when applied to the soil.

This change is brought about by the taking up of carbon dioxide; it takes 44 pounds of carbon dioxide to convert 56 pounds of calcium oxide into the carbonate form. Thus, 1 ton of pure burnt lime will produce 3,571 pounds of calcium carbonate. Since limestones are seldom pure, it can be seen from these figures that 1 ton of burnt lime is approximately equivalent to 2 tons of calcium carbonate. Water-slaked lime, *i.e.*, calcium hydroxide and magnesium hydroxide, is made by water-slaking burnt lime. From 56 pounds of pure burnt lime 74 pounds of water-

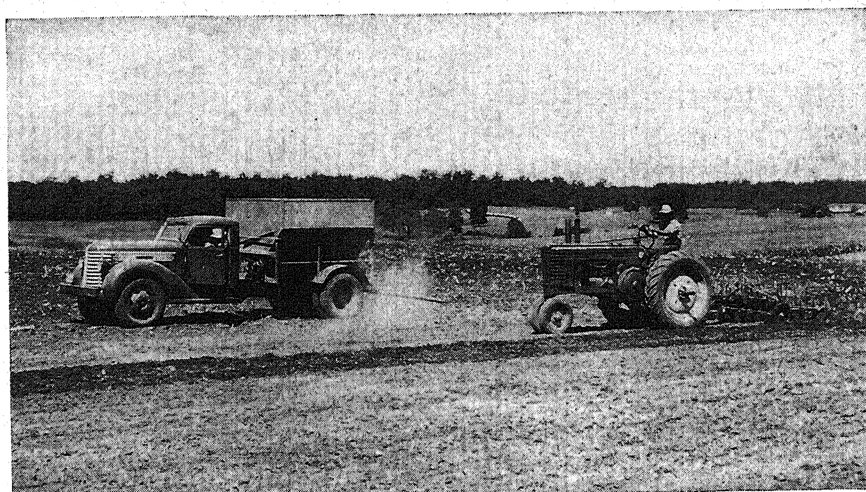

FIG. 9. Lime being distributed on corn stubble and then worked into soil by disking while preparing a seedbed for small grain.

slaked lime may be yielded. Therefore, 1 ton of burnt lime is approximately equivalent to 1½ tons of water-slaked lime.

Ground limestone and marls, with the exception of the shell marls, are carbonates of calcium or magnesium. The shell marls and ground shells are carbonates of calcium. These materials are usually, but incorrectly, spoken of as carbonates of lime. There has been much controversy in the past as to the relative values of these different forms of lime. From a theoretical standpoint, 1 ton of burnt or quicklime is approximately equivalent to 1½ tons of water-slaked lime or 2 tons of the carbonate.

Form of Lime to Use. Data from the majority of experiment stations in the United States show practically the same results from the application of an equivalent quantity of calcium oxide to the soil, without regard to the kind of lime used, whether burnt lime, hydrated lime, ground limestone, or marl.

Miller and Krusekopf,[9] in Missouri, say, "The kind of lime to use

should be determined almost entirely by the kind which gives the greatest sweetening power for a dollar invested."

Location of Farm as Affecting Economy in Forms of Lime. In the choice of a liming material, distance from the railroad station is often an important consideration. Concentrated materials such as burnt and water-slaked lime are more costly to buy but are less costly to haul and spread per unit of available oxide and are needed in less quantity per acre. Coarse carbonate materials, such as screenings and coarsely ground limestone, on the other hand, have a cheaper initial cost but a high hauling and spreading expense. Consequently, the latter may prove more economical close to the source of production. For reverse reasons concentrated materials such as burnt lime and water-slaked lime often prove cheapest on outlying farms. Intermediate goods, such as finely ground limestone and marl of high purity, and the lower grades of burnt and water-slaked limes fall between these extremes. The coarser materials may be economical within a 1-mile zone of the railroad station. The economy zone for pulverized limestone is placed at 1 to 5 miles, while burnt limes fall within the outer zone ranging from 5 to 10 miles or more. These divisions are not absolute but merely serve to point out the range of distribution as influenced by concentration.

From a farmer's standpoint the most important consideration in reference to forms of lime is the cost of a given quantity of available oxides spread on the land. In arriving at the price of lime applied to the land, one must consider all costs including freight, hauling, and spreading.

Fineness of Ground Limestone. White and Gardner,[10] in Pennsylvania, tested graded limestone on its effect in correcting acidity. The 100-mesh stone produced an alkaline reaction the first year, but by the end of the third year the soil again showed slight acidity; the 60-mesh stone did not give an alkaline soil until the second year; the 20-mesh stone did not give an alkaline soil until the third year; whereas the soil to which the 8-mesh stone was applied still showed a lime requirement of 3,000 pounds at the end of the third year.

Shorey[11] states that high-calcium limestone for pulverizing should usually contain 90 per cent or more of carbonate of lime. Pulverized limestone should be ground fine enough for all material to pass a 20-mesh sieve and for at least 75 per cent of it to pass a 100-mesh sieve. The finer the limestone is ground the more it will cost and the more soluble and immediately effective it will be in the soil. There is, however, a point beyond which added expense for fine grinding is not warranted because the increased crop production does not offset the increased cost of material. Very finely ground limestone is produced at a greater cost

than the coarser materials, and in some cases it is economical to buy the coarser materials even though they may be less available and less efficient from a crop-production standpoint. Thus the increased cost of very finely ground limestone, together with the rapidity with which it disappears from the soil, as compared with coarser material, leads to the conclusion that an application of material, all of which will pass a 20-mesh sieve and include all the fine material incident to such grinding, is sufficiently fine for soil improvement if applied somewhat in excess of the immediate need of the soil.

Rate of Applications. No definite rule can be given as to the amount of lime to apply. This will depend upon both crop and soil. It is obvious that crops requiring large quantities of lime planted on very acid soils should receive more lime than less exacting crops on soils with a comparatively low lime requirement. Lime may be applied in sufficient quantities to meet the lime requirement of the soil as determined by chemical tests. However, good results are often obtained from the use of much smaller quantities than are necessary to meet the lime requirement as determined by these tests. The rule followed by many farmers is to apply 1 ton of burnt lime or its equivalent to the acre on clay soils and half this amount on sandy soils.

Midgley and Weiser,[12] in Vermont, found that small applications of lime proved more effective per unit used than larger dosages. Lime leaching losses increased roughly in proportion as the amounts applied were increased. Small applications brought about greater pH changes per unit of lime than occurred when heavier ones were made. Larger crop responses per unit of lime were always secured when applications were made at the lower rates. Some crops may be severely damaged when large amounts of lime are sown on some acid soils, whereas such injuries never occur on neutral or basic soils when similarly limed. However, these injurious effects tend to disappear as time elapses.

Albrecht and Poirot,[13] in Missouri, demonstrated that quantities of lime as small as 300 pounds of 30-mesh material per acre, combined with inoculated soil and drilled with the clover seed, were as effective as 5,000 pounds of 10-mesh limestone broadcast for establishing the clover crop on lime-deficient Gerard silt loam.

Time and Method of Application. To be most effective, lime should be thoroughly mixed with the plowed portion of the soil. This mixing is usually done most economically by broadcasting lime on newly plowed land and mixing it with the soil by the disking and harrowing necessary to prepare the seedbed. However, economy in hauling may have an important influence on the method of application. It is often more convenient to haul lime during the winter or at some other season when other

farm work is not pressing. Sometimes land has not been plowed at these seasons; and if the lime is hauled, it must either be stored or spread on unplowed land. In recent years many farmers have followed the practice of hauling lime when convenient and spreading on the fields where needed, whether they have been plowed or not. Even when lime is spread and plowed under, it has given satisfactory results. In some cases lime is spread on winter grains after seeding. This practice has proved desirable when it is not practicable to apply the lime before

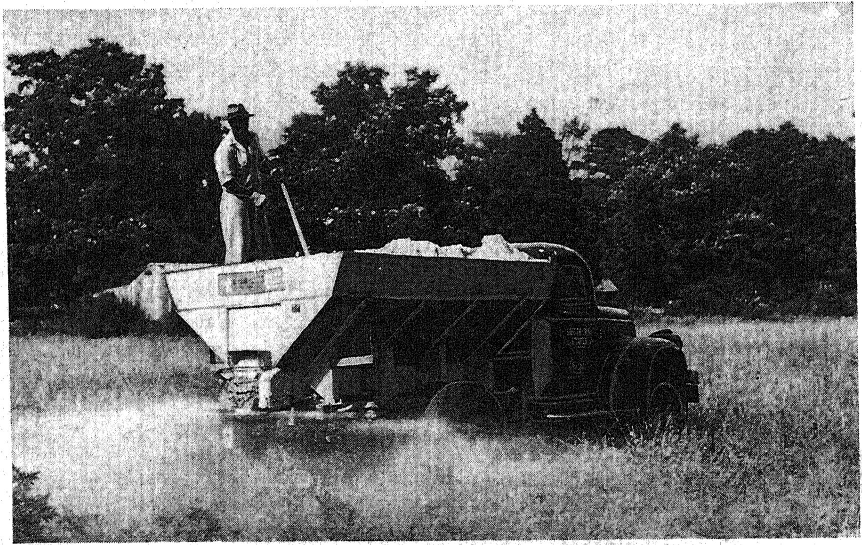

FIG. 10. A lime-distributing truck that scatters lime uniformly over a wide area.

seeding, especially when clover is to be seeded on the grain land the followed spring. The time of application is often immaterial and in farm practice is usually determined by the distribution of labor. The place in the crop rotation should be usually just before the crop most responsive to lime, provided this time is convenient and does not interfere with economy in the use of labor. When it is not possible to apply lime at this time, it may be applied to some other crop in the rotation.

Frequency of Application. The frequency of application depends somewhat upon the rate of application. It has been suggested that lime be used in sufficient quantities to meet the lime requirement of the soil when used for the first time, and that thereafter smaller quantities be used once in each rotation course, depending upon the length of the rotation.

Relation of Liming to Hydrogen-ion Concentration of Soils. At present the most popular method of determining the lime needs of soils

is that of measuring their hydrogen-ion concentration. The symbol pH, an abbreviation of "potential due to hydrogen," is now generally used for expressing the intensity of reaction. In this method, pH 7 expresses neutrality, whereas any numbers above pH 7 express varying degrees of basicity and any numbers below pH 7 express varying degrees of acidity. Thus a soil showing pH 7.5 would be slightly alkaline, and a soil of pH 6.5 would be slightly acid.

Suitable pH ranges for various field crops are as follows:

6.5 to 7.5—Alfalfa, sweet clover.
6.0 to 7.0—Alsike clover, red clover, white clover.
5.5 to 7.0—Barley, corn, cowpeas, crimson clover, grasses, lespedeza, oats, millet, rye, sorghum, soybeans, wheat.
5.5 to 6.5—Peanuts, velvet beans, vetch.
5.0 to 6.5—Buckwheat.
5.0 to 6.0—Cotton.
5.0 to 5.6—Tobacco.

Obviously the degree of acidity of the soil would have an important bearing on the response of any crop to liming. For example, potatoes and tobacco are usually listed as crops injured by liming. However, both of these crops respond to the use of lime in moderate amounts on very acid soils, but if the soil is limed sufficiently to make it a favorable medium for the development of potato scab, or of root rot in tobacco, yield and quality of both crops are reduced.

The profits from the use of lime depend upon the condition of the soil and the crops grown. If soils are poor in bases, lime will give profitable returns on all the most important crops of the United States, with the probable exception of cotton and potatoes. The two last-mentioned crops may be indirectly benefited by the use of lime when grown in rotation with clovers and other legumes.

The clovers are greatly benefited by the use of lime, and when the soil is limed they add more organic matter and nitrogen to the soil. The use of lime usually makes it easier to produce good crops of clover. Where clovers can be grown successfully, most adapted crops thrive. Many of the beneficial effects commonly attributed to lime are really directly due to the growth of clover made possible by the use of lime.

Benefits from the Use of Lime. Most soils contain sufficient calcium for the nutrition of plants, but even in view of this fact lime is frequently applied. In addition to supplying calcium, lime aids in bringing about changes in soils that make them more suitable for the growth of crops, and as a result crop yields are frequently increased.

Lime has the following effects when applied to the soil: (1) correction

of soil acidity, (2) improvement of the physical condition, (3) stimulation of the proper decomposition of organic matter, (4) probable increase in availability of other minerals in the soil, (5) general increase in the efficiency of manure and fertilizers; and (6) facilitation of the production of green-manure crops for soil improvement.

Effect of Lime on Crop Yields. The National Lime Association reports that results of eleven state experiment stations on sixteen field crops shows that each dollar invested in lime returns an average of over $3. In Ohio, the Association reports that the difference in favor of lime was $36.74 an acre per rotation on unfertilized land, and $41.92 an acre per rotation on fertilized land.

Indications of the Need of Lime. The first symptoms of soil acidity are the partial or complete failure of those crops, common to the locality, most sensitive to soil acidity and the encroachment on the land of acid-tolerant species of weeds and grasses. Sheep sorrel, wild daisies, yellow trefoil, poverty grass, dewberries, redtop, broom sedge, the bent grasses, and the plantains are common weed indicators of soil acidity. The failure of such lime-loving plants as red clover, sweet clover, and alfalfa may also be considered an indication of the need of lime, if other soil conditions are right.

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Topics for Discussion

1. Do farmers actually have anything to sell but labor and plant food?
2. Are commercial fertilizers stimulants or plant foods?
3. Is it practicable to produce on the farm all the nitrogen needed for crops?
4. What countries produce the most nitrogen, phosphorus, and potassium for the world's fertilizer industry?
5. Can lime take the place of manures and fertilizers?
6. In case lime is not available for farm use, what is the best substitute?
7. Is overliming possible?
8. Assuming that no fertilizer is used, will a limed farm become richer or poorer?

CHAPTER IX

MANURES

Organic matter is the basis of soil productivity. It may be incorporated in the soil from several sources. Among the most important sources are barnyard manure and green manure.

BARNYARD MANURE

Barnyard manure was one of the first materials used on the soil for the purpose of increasing productivity. Before the Christian Era, Virgil wrote: "Sprinkle sordid ashes all around and load with fattening dung thy fallow ground." The fact that many other early writings refer to the use of barnyard manure leaves little doubt that the benefit derived from this material was recognized by our earliest farmers. However, new countries rarely appreciate the value of barnyard manure. It is not until the productivity of the soil has begun to decline that manure is given the attention that its value justifies. In comparatively recent years it was not an uncommon sight to see manure on American farms being drawn to the nearest ditch or stream for the simple purpose of getting it out of the way, and many ranchers would have welcomed the services of a Hercules to clean their barns of the accumulations no less undesirable than those of the Augean stables.

Salter and Schollenberger[1] state that manure to the amount of a billion tons a year is produced on American farms. Theoretically it is capable of producing 3 billion dollars' worth of increase in crops, but only a small part of its value is actually realized. Much of the loss is due to faulty handling.

Effects of Manure. The results obtained from the use of manure vary with the locality, soil, and crop. However, the results of experiments in various parts of the United States show that its application gives paying results in practically every locality.

It is generally agreed that the chief benefits from manure are indirect. By supplying humus, it improves the tilth or physical character of the soil as well as the water-holding capacity, aeration, and temperature relations, and it has a favorable effect on the biological activities of lower organisms that work over the stock of plant nutrients in the soil and make them available for immediate use (Salter and Schollenberger[1]).

Economy in the Use of Manure and Relative Value for Different Crops. All common field crops respond to applications of barnyard manure, and the returns are usually profitable. However, there are some indications that in a given rotation higher returns are obtained when the manure is applied to one crop than to other crops. In general, the crop that gives the highest money returns per acre gives the best profits from the use of manure. In the case of truck crops it often pays to make heavy applications of manure to each crop grown in the rotation. In general farming, the convenience of application is often as important as the relative profit to be obtained from the different crops.

Manure can usually be more conveniently hauled and distributed during the winter months, but lands are likely to be wet during the winter, and cultivated fields are too muddy to drive over, except when frozen. In this case it is often economical to apply manure to the grass crop in the rotation even though some other crops in the rotation might give a higher return from its use. Where hay has a relatively high value, it may give a larger return from the use of manure than other crops in the rotation.

It is not advisable to apply manure that contains much coarse material, such as cornstalks, to hay fields, as these materials may remain on the field and be raked up with the hay, in which event the quality of the hay would be reduced. Such coarse manures should be plowed under before crops such as corn and sorghum are planted, since these crops seem to have the ability to use these coarse materials to good advantage.

On soils that are low in organic matter and nitrogen, manure may be used advantageously as a top-dressing to small grains, and it is particularly valuable for spreading on thin eroded spots in such fields. However, manure should not be used as a top-dressing on small-grain fields known to be rich in nitrogen, as its relatively high nitrogen content may have a tendency to weaken the straw. Falling down or "lodging" might then result. Fresh manure is not advocated for potatoes, as it has a tendency to increase scabbiness, if the spores of the scab disease exist in the soil or on the tubers planted.

In general farm practice, special crops of high acre value usually receive first consideration in the use of manure. If more manure is available than is needed for such crops, it is often applied to the corn crop or is hauled out during the winter and scattered on the hay or pasture fields.

Time and Rate of Application. As intimated previously, manure is usually hauled out when such work does not conflict with the more pressing work, such as seeding, cultivating, and harvesting. Numerous

experiments have been conducted to determine the value of manure applied during the winter months and plowed into the soil in preparation for a summer crop, as compared with manure applied on the plowed land in the spring and harrowed into the soil. The evidence from these experiments is conflicting, but the differences in results are small in all cases, and experimenters usually agree that convenience of application is of greater importance than time of application.

The rate of application of manure varies with the kind of crop to which it is applied. With crops of high acre value very heavy applications are usually advised. With truck crops, 30 tons or more to the acre may often be used to advantage. In general farming, light applications have usually given higher returns per ton of manure than heavy applications.

Harris,[2] at the Utah Experiment Station, found that a 10-ton application of manure to sugar beets produced an increased yield of about 1 ton of beets for each ton of manure. Five tons to the acre produced nearly 2 tons of beets for each ton of manure, but where there was an application of as much as 40 tons to the acre the increase was only about 0.4 ton of beets for each ton of manure. Where potatoes were manured at the rate of 5 tons to the acre, the yield was increased by nearly 13 bushels for each ton of manure but, where 40 tons were applied, the increase was only 4.3 bushels for each ton. In the case of corn, a 5-ton application of manure produced an increase of 3.83 bushels for each ton of manure and a 15-ton application produced only 1.61 bushels of grain for each ton of manure.

One of the great advantages of the modern manure spreader is that it will scatter small quantities of manure evenly over the soil. Since it is possible in this way to manure more of the farm each year with the limited quantity of manure at hand, the farmer receives a larger return for each ton of manure applied.

Crops to Which Manure Should Be Applied. Williams,[3] at the Ohio station, reports that as an average for an 11-year period the increase from manure applied to different crops in the rotation was as shown in Table 5.

Annual Application vs. Once in Rotation. Kipps and Hutcheson[4] present data to show the effects on yields of crops by applying 4 tons of manure annually on all crops in a 4-year rotation and by applying 16 tons once in 4 years. These data are presented in Table 6.

Factors Influencing the Value of Barnyard Manure. The value of manure varies considerably according to the kind and age of animals, the kind and amount of food consumed, the kind and amount of bedding used, and the system followed in collecting, preserving, and utilizing the manure.

TABLE 5. VALUE OF INCREASE FROM APPLYING MANURE TO DIFFERENT CROPS

Crops receiving phosphated manure	11-year average increase per acre				
	Corn, bu.	Oats, bu.	Wheat, bu.	Clover, lb.	Value of increase per rotation
Corn and wheat*	16.57	6.95	11.42	1078	$39.59
All on corn	19.95	8.05	9.44	815	37.46
All on wheat	13.83	5.72	13.30	1259	41.36
All on clover	15.03	4.16	5.75	1313	30.66

* One-half to each.

TABLE 6. EFFECT ON YIELDS OF CROPS OF APPLICATIONS OF MANURE ANNUALLY AND ONCE IN 4 YEARS
(Average 1914 to 1937 inclusive)

Treatment per acre	Corn, bu.	Marketable corn, per cent	Wheat, bu.	Clover hay, tons	Mixed hay, tons
4 tons manure annually	61.91	86.24	24.21	2.50	2.61
16 tons manure once in 4 years (before corn)	58.40	85.40	23.30	2.03	3.03
No manure	32.51	76.56	6.60	0.82	0.96

Class of Animals. The composition and amounts of excrement produced by farm animals are shown in Table 7. From these data it is seen that there are considerable variations in composition as well as in amounts produced (Salter and Schollenberger[1]).

TABLE 7. COMPOSITION AND AMOUNTS OF EXCREMENT FROM FARM ANIMALS

Kind of animal	Daily production per animal, lb.		Composition of fresh excrement							
			Nitrogen (N), per cent		Phosphoric acid (P_2O_5), per cent		Potash (K_2O), per cent		Lime (CaO), per cent	
	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Liquid
Horses	35.5	8.0	0.50	1.20	0.30	Trace	0.24	1.50	0.15	0.45
Cattle	52.0	20.0	0.32	0.95	0.21	0.03	0.16	0.95	0.34	0.01
Sheep	2.5	1.5	0.65	1.68	0.46	0.03	0.23	2.10	0.46	0.16
Hogs	6.0	3.5	0.60	0.30	0.46	0.12	0.44	1.00	0.09	0.00
Hens	0.1	....	1.00	....	0.80	....	0.40			

Food Consumed. The fertilizing value of the manure is derived from that of the food consumed and varies accordingly. Manure from animals fed high-protein feeds is much more valuable than from those fed on feeds of low food value. Salter and Schollenberger[1] state that manure from grass-fed animals, growing stock, and milk stock is less rich than that from animals being fattened or from work animals liberally fed on concentrates. Growing animals and those producing milk utilize considerably more of the nitrogen, phosphoric acid, and calcium of their food for flesh, bone, and milk than is retained by mature stock on maintenance rations, working, or even fattening.

The amount of feed consumed also has a considerable influence on the value of the manure produced, as animals on a scant ration digest their food much more thoroughly than those receiving a full feed.

Bedding Used. Since materials used as bedding for animals vary in chemical composition, it is obvious that the character of the bedding will influence the composition of the manure obtained. For example, when bean straw is used for bedding, the manure will be richer in nitrogen than if the same amount of sawdust is used, because the former contains more nitrogen.

Care of Manure. The liability of manure to a rapid loss of its constituents makes its proper care and handling an extremely important consideration. The richer the original manure is in nitrogen, phosphoric acid, and potash, the greater is the liability to loss. This tendency is due to the more rapid fermentation of a substance rich in nitrogenous materials and to the greater possibility of loss from leaching in substances containing large amounts of soluble mineral salts.

This loss is not entirely preventable but can be greatly reduced by proper care. Due to fermentation and leaching, considerable loss of manure occurs in the barn, which can be reduced by keeping the floors well bedded with some material that has high absorbent properties. Such material should be supplied in sufficient quantities to absorb all liquids and keep the animals clean. Too much litter, although it does not reduce the manure's actual value, dilutes the manure with material that often does not carry large quantities of fertilizing ingredients. The next consideration in the care of manure is a tight floor. According to Salter and Schollenberger,[1] one-fourth of the liquid excrement from animals is lost on earth floors. They calculate that the saving in two feeding periods of 6 months each was sufficient to pay for the floor.

Where feasible, it is advisable to haul manure to the field as soon as it is produced. Manure scattered on fields loses very little from fermentation, and when leaching occurs the soluble portions of the manure are

carried directly into the soil. It is not always convenient to haul manure directly to the field, and in most cases storage must be provided.

Storing Manure. The two fundamental requirements for the proper care of manure are to prevent leaching and to minimize the loss of nitrogen from fermentation. These two ends are best obtained by storing the manure in covered sheds with tight bottoms and keeping it carefully spread and moistened. Where covered sheds with tight bottoms can be provided for livestock, the loss in manure can be reduced to a minimum. Leaching is prevented by the roof and tight floor, the trampling of the animals keeps the manure compact, and the urine furnishes moisture that reduces fermentation. Untrampled manure in covered sheds loses more than three times as much of its fertilizing value as trampled manure in covered sheds.

When covered sheds are impracticable, the next best method of storing manure is in covered concrete pits. Both the solid and the liquid excrement are stored in these pits until it is convenient to haul them to the field. The manure should be well packed in such pits, and sufficient moisture should be provided to prevent heating. The most wasteful method of storing manure is in piles fully exposed to the weather. However, it is often necessary to expose manure to the weather, and, when such is the case, an excavation should be made where the pile is to be located so that the drainage will be toward rather than away from the heap. The sides of the pile should be steep so as to shed water rapidly, and each addition of manure should be firmly packed. In dry weather the manure should be moistened to prevent burning, and the pile should be hauled to the field as soon as practicable.

Well-rotted manure is often desirable for trucking and gardening. Manure loses a large amount of its fertilizing value in the rotting process, but the resulting product is relatively richer in plant nutrients than fresh manure, because rotting reduces the total weight of the manure more rapidly than it reduces the fertilizing constituents. Thus well-rotted manure is a more concentrated product than fresh manure. Care should be taken to keep manure that is undergoing the rotting process moist and well packed, so as to reduce loss as much as possible.

How Manure Increases Crop Yields. Manure increases crop yields probably for the following reasons: (1) It carries a considerable quantity of elements necessary for plant growth that are often insufficient in the soil; (2) it adds organic matter to the soil; and (3) it increases the bacterial content of soils.

Source of Plant Nutrients. Mixed barnyard manure contains, on an average, about 0.5 per cent nitrogen, 0.25 per cent phosphoric acid, and 0.5 per cent potash. These amounts seem small when manure is com-

pared with high-grade commercial fertilizers, but, when the enormous amount of manure produced by the ordinary farm animals in a year is considered, the total quantity of plant nutrients produced reaches a relatively high figure. Thus 100 pounds of a 10-5-10 fertilizer is equivalent to an average ton of manure, so far as plant nutrients are concerned, and can be purchased and applied at less cost. Unfortunately, manure depreciates rapidly in value when not properly cared for, and few farmers obtain the value from the manure of their animals that these figures indicate as possible.

It should be noted that manure is not a well-balanced fertilizer, being rather low in phosphoric acid and relatively high in nitrogen and potash. As many soils are poor in phosphoric acid, the efficiency of manure is often increased by the addition of phosphate fertilizers.

Source of Organic Matter. Manure contains a high percentage of organic matter, but under ordinary conditions only a comparatively small proportion of its organic matter is returned to the land when manure is applied. However, since all the organic matter is produced from materials that come from the atmosphere, the organic matter that is returned to the soil can be counted as a real addition to the soil. Therefore, manure is considered an important source of organic matter.

Source of Bacteria. The addition of manure to the soil greatly increases the bacterial content over a considerable period.

GREEN MANURE

A green-manure crop is one used for turning into the soil, whether planted for that purpose or not, and irrespective of whether the crop is turned under while still green or after maturity. The function of a green-manure crop is to add organic matter to the soil. As an incident to this function the nitrogen supply of the soil may be increased and certain minerals made more readily available, these effects in turn increasing the productivity of the soil (Pieters and McKee[5]).*

The practice of green manuring is very ancient. The Greeks turned under broad beans 300 years before the Christian Era, and the planting of lupines and beans for soil improvement was a common practice in the early years of the Roman Republic. The Chinese wrote about the fertilizing value of grass and weeds several hundred years before our era. Buckwheat, oats, and rye were used in this way by the American colonists before the middle of the eighteenth century, and toward the end of that century Maryland and Virginia farmers used the partridge pea for soil improvement.

* An excellent treatise on this subject by these authors may be found in the 1938 Yearbook of Agriculture. Their subject matter was used to a great extent in the preparation of this portion of the chapter dealing with green manures.

Importance of Organic Matter in Soil. The amount of organic matter that may accumulate through decay of roots or the addition of green manures will vary with conditions. Obviously, not all the plant material turned under becomes part of the soil humus. A large part disappears during decay as carbon dioxide. Under some conditions, as on sandy soil in a hot climate, this loss may be so excessive that no permanent addition to the soil organic matter is made even by turning under a heavy green manure crop.

No very large addition to the soil organic matter can be expected from turning under a single green-manure crop. If a crop of vetch that will yield a ton of dry matter per acre is turned under, about one-half will be quickly lost as carbon dioxide or in other ways, and the balance, or about 1,000 pounds per acre, will become for a limited time a part of the humus. If a soil contains 2 per cent of organic matter in the surface soil, the organic matter will weigh approximately 40,000 pounds per acre. By adding 1,000 pounds a year, 40 years would be required to double the organic matter in this surface soil, if it were all permanently retained. This illustration, although a rough one, is introduced to point out that in the main the object of green manuring must be to maintain rather than to increase the quantity of organic matter in soils.

Legumes and Nonlegumes. Both legumes and nonlegumes are used as cover and green-manure crops. The chief difference between them is that legumes add both organic matter and nitrogen to the soil, whereas nonlegumes add organic matter only.

The amount of nitrogen added to the soil by legumes depends on the kind of legume, the condition of the stand, and the stage of growth at which the legume is turned under.

The amount of nitrogen in a legume when turned under represents the nitrogen it has taken from both the soil and the air, but the amount taken from the air is all that is really added to the soil. The relative amounts derived from each of these sources are difficult to determine, and it can only be stated that as a broad average about two-thirds of the nitrogen in a legume is believed to have been taken from the air and one-third from the soil.

Utilization of Green Manures. Cover and green-manure crops should be used when they least interfere with the regular cash crops. It is generally considered that giving over the entire crop season exclusively to a green-manure crop is seldom profitable.

It should be made clear that when large quantities of green organic matter are turned under or otherwise incorporated with the soil, some time must be allowed to elapse before planting a succeeding crop, in order to avoid injury, by decomposition products, to the seedlings of the crop to be planted. In the South, a green-manure crop should be turned

under about 2 weeks before planting corn and 3 weeks before planting cotton.

Effect on Yield of Subsequent Crops. In Georgia and Louisiana increases in cotton yields following the turning under of legumes ranged in round numbers from 22 to 100 per cent in various experiments.

Similar increases have been shown in the case of corn, the turning under of a winter legume having usually increased the corn yields in experiments in Georgia, Mississippi, South Carolina, and Virginia from 24 to 78 per cent. In the Corn Belt the turning under of a sweet clover crop on poor to medium soils increased corn yields by 64 per cent and on soil in good tilth by 36 per cent.

In Wisconsin, potatoes grown after red clover was turned under without fertilizer produced more than 234 bushels per acre, compared with about 183 bushels on heavily manured or fertilized land, and about 168 bushels on the check plot.

In Iowa, the turning under of sweet clover produced a 17 per cent increase in corn and an 18 per cent increase in oats. In Illinois, corn, following sweet clover turned under, yielded 41 per cent more than on plots without sweet clover.

Although a nonlegume will add organic matter to the soil, the soil microorganisms, as previously explained, require nitrogen to effect decay. The turning under of rye or other grain has commonly resulted in a decrease in the following corn or cotton crop because of exhaustion of the soil nitrogen. The age of the green-manure crop when it is turned under has an important influence on the yield of the subsequent crop. It is evident that grain cover crops must be turned under young or adequate supplies of nitrogen must be added to the soil to facilitate decay. Young rye contains a higher percentage of nitrogen and a lower percentage of fiber than old rye.

Residual Effect. When a crop such as clover, vetch, or cowpeas that could have been cut for hay is turned under, the increase in the following crop may or may not be great enough to pay for the hay lost. In comparing the returns, however, it should be taken into consideration that the green manure may have a marked effect on yields of subsequent crops for 2 or more years.

At the Alabama Experiment Station, corn the second year after velvet beans outyielded that without green manure by 40 per cent, and in the third year the effect of the green manure was still evident.

At the Oklahoma Experiment Station, an increased yield of wheat was obtained for 3 years following a green-manure crop of Austrian winter field peas, and, at the Kansas Station, alfalfa cropped for a period of 2 years produced a favorable residual effect on succeeding wheat crops over a period of at least 8 years.

The Rothamstead Experiment Station, in England, reports that the residual effect of cultivated legumes was apparent in the yields of cereals for several years after the legumes had ceased to be grown, and the Central Experimental Farms, at Ottawa, Canada, have reported increased yields of corn, oats, and potatoes in the second, third, and fourth years, respectively, owing to the residual effect of a previously grown red clover crop.

Extent Grown. It has been estimated that in Indiana 50,000 acres of sweet clover are turned under annually for green manure preceding corn crops, and in Ohio probably 30,000 acres. In Illinois an estimate of 300,000 to 400,000 acres used for soil improvement may be reasonable. In the Southern states the estimated figures of the acreage planted to Austrian winter peas and hairy vetch ranges from 100,000 to 400,000 acres for the various states.

Green-manure Crops. The most popular green-manure crops are hairy vetch, Austrian winter peas, rye, crimson clover, crotalaria, sweet clover, and alfalfa.[5]

Other crops, such as red clover in the North and lespedeza in the South, although rarely used exclusively for green manuring, have a distinct place in a soil-conservation program.

Still other crops that are used to some extent as green manure are buckwheat, sesbania, Florida beggarweed, soybeans, sudan grass, velvet beans, and weeds.

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Topics for Discussion

1. Do farm manures actually bring any plant food to the farm?

2. Does a farmer who does not house livestock get any soil improvement from manure?

3. Is it possible to build up a worn-out farm by keeping livestock and purchasing no plant food?

4. With labor at the current price how far can one afford to haul manure for a corn crop?

5. What becomes of the plant material turned under as a green-manure crop?

CHAPTER X

PREPARATION OF THE SEEDBED

The preparation of a good seedbed is one of the most important factors in profitable and economic crop production. No other factor will entirely take the place of a well-prepared seedbed, not even good seed, proper fertilization, judicious cultivation, and optimum moisture supply.

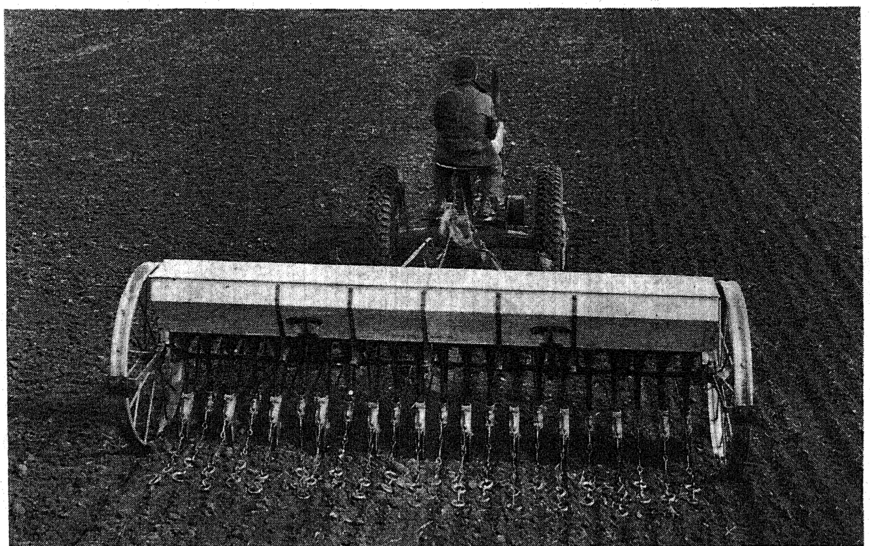

Fig. 11. Seeding small grain on a well-prepared seedbed. (*Courtesy of American Iron and Steel Institute.*)

Right Preparation Increases Yield. The chief reason for preparing the seedbed well is to secure increased crop yields. Good crops usually cannot be produced on poorly prepared ground. There are numerous results of experiments that bear out this statement.

At the Ohio Experiment Station, Williams and Welton[1] compared the results obtained from corn, oats, wheat, and clover in rotation on land plowed in the ordinary way, on land plowed deep, and on land subsoiled. The results show that deep plowing and subsoiling have not increased the yields of these crops. The deeper plowings are more

expensive, and under the conditions of these experiments ordinary plowing is to be recommended.

Leighty and Taylor[2] found that over a 6-year period the yields of winter wheat were practically the same on a disked as on a plowed seedbed.

Richey[3] states in regard to the depth of plowing for corn, "Plowing less than 5 or 6 inches deep usually is insufficient to turn under surface growth and trash properly so that it will be out of the way. Plowing more than 7 or 8 inches deep, or subsoiling, usually is wasted energy."

Nelson[4] found, in Wyoming, that spring wheat on disked corn land produced 12.8 bushels per acre as an average for 16 years; on spring-plowed corn land, 12.0 bushels; on fall-plowed corn land, 9.0 bushels; and on summer fallow, 12.6 bushels. Plowing is a minor factor in spring-wheat production in Wyoming.

Cardon[5] found, in Utah, that the 5-year average yield of wheat on cultivated fallow was 17 bushels per acre. The yield from uncultivated fallow was 13 bushels, a difference of 4 bushels in favor of cultivated seedbed. The soil used was a clay loam.

Cole and Mathews[6] report that at Hays, Kansas, where winter wheat is grown following winter wheat, the yields obtained by beginning cultivation immediately after harvest may be as much as 50 per cent greater than where cultivation is delayed until near seeding time. The benefits of early tillage are greatly reduced, however, farther west in the state where the rainfall during this period is not heavy enough to provide for storage in the soil.

Kiesselbach and others[7] found in an 11-year comparison in Nebraska that early spring plowing yielded 5 per cent more corn per acre than late spring plowing and 18 per cent more than fall plowing.

The experiments cited show that good preparation of the seedbed is profitable. The results also show that no definite statement can be made as to the amount and nature of the preparation that will be most advisable. The existing conditions necessarily modify to some extent the advice to be given in regard to the preparation of the land for planting.

Implements Used in Preparation of the Seedbed. The implements used in preparing the seedbed differ in the depth they stir the soil, their effectiveness in destroying weeds, the position in which they leave the crop residue, and in the cost of operation. In recent years emphasis has been laid on the position in which the crop residue is left. Duly and Mathews[8] give four methods of disposing of crop residues: (1) removing from the field or burning, (2) completely turning under by plowing, (3) partly burying by disking or some similar operation, and (4) leaving entirely on the surface by some method of subsurface cultivation. The

three main classes of implements used in preparing the seedbed are plows, harrows, and compacters.

Plows. There are several types of plows, but the most common one is the ordinary moldboard plow. Moldboard plows are divided into stubble, general-purpose, and sod plows, according to the kind of moldboard. The stubble plow, with its short, strongly curved moldboard, pulverizes the soil to a great degree. This type of plow is good to use in old cultivated lands. But little pulverization is obtained by means of the sod plow, which has a long, slightly curving moldboard. The general-purpose plow has a moldboard intermediate in length and curvature between the stubble and sod plows.

Some of the other types of plows are the disk, subsoil, and hillside plows, and middlebusters and listers. The disk plow is especially good for plowing hard dry land. The subsoil plow is employed to loosen the soil in the bottom of the furrow made by the ordinary plow. The hillside or swivel plow is a form of moldboard plow made in such a way that the moldboard may be reversed. This type of plow is used for plowing on comparatively steep hillsides.

Middlebusters and listers are similar in appearance to a double plow with a right- and a left-hand bottom mounted back to back (Gray[9]). They are used to prepare ridges in which to plant crops bedded in rows, such as cotton, potatoes, and sweet potatoes. The land may be broken flat and later ridged with the middlebuster. The tool is also used to clean out middles, break out the rows, and sometimes rebust. In semiarid regions it is used for placing the soil in ridges to hold moisture and prevent blowing. In these regions the tool may be mounted on a planter called a "lister," with the seed being planted in the resulting furrow.

Harrows. Of the harrows used in preparation of the seedbed may be mentioned the spike tooth, spring tooth, acme or blade, and disk.

The spike-tooth harrow usually consists of two to four sections, the teeth being set at various angles by means of levers. It is very effective in pulverizing and to some degree in compacting land that has been freshly plowed. The "A" harrow is used by some farmers instead of the spike tooth. The spring-tooth harrow is more efficient in loosening soil than the spike-tooth harrow and is used mostly on soils low in organic matter and poor in physical condition. The acme or blade harrow serves a very useful purpose in pulverizing and compacting the soil. The disk harrow is of several types: the solid disk, the cut-away disk, and the spading disk. The disk harrow ranks next in importance to the plow in the preparation of land for seeding. It is very effective in stirring, pulverizing, and compacting the soil.

Compacters. There are various forms of implements used to compact the soil. Among these are the smooth or drum roller, the culti-packer or corrugated roller, the bar roller, plankers, subsurface packers, and treaders.

Compacters are used to crush clods on heavier soils, to firm the soil in case of the lighter kinds of soils, such as sands and sandy loams, and to smooth the surface of the soil. The subsurface compacters are used

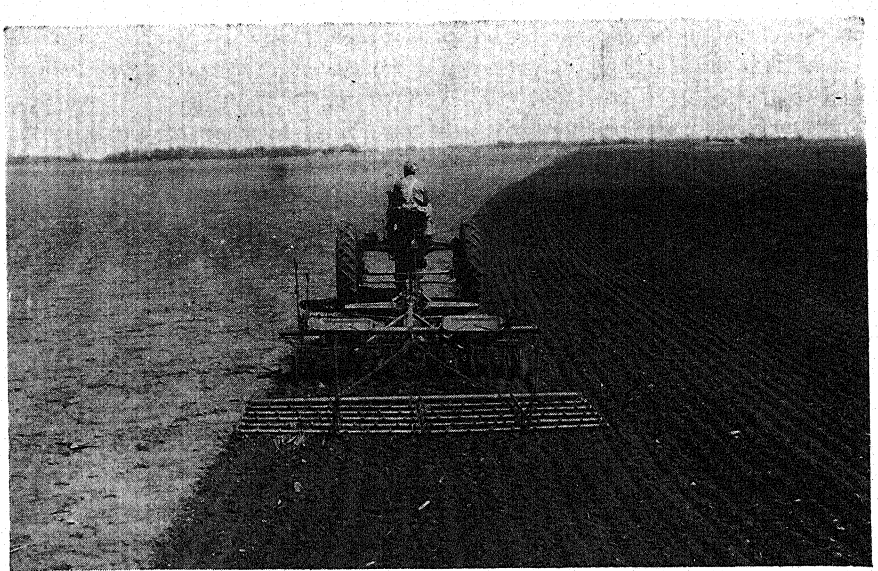

FIG. 12. Preparing a seedbed with a tandem disk and spike-tooth harrow.

in arid and semiarid regions to firm the soil beneath the surface. In this way moisture is better distributed and conserved.

The smooth roller is used extensively but is being very largely replaced by the culti-packer, as the latter crushes the clods to a greater degree. The culti-packer is also effective in firming the soil and leaves the surface of the ground covered with a thin mulch instead of smooth, as does the smooth roller. The bar roller is said to be intermediate in effectiveness between the smooth roller and the culti-packer. Plankers are excellent for crushing clods and leveling the ground, but they are not very efficient in compacting the soil. The treader is used to pack and pulverize the soil in stubble-mulch farming.

Stubble Mulch. The process of leaving the residue on the surface while the land is farmed is called "stubble-mulch farming" or "stubble mulching." According to Duly and Mathews,[8] it involves tillage beneath the residues for soil pulverization and weed control, final preparation of

a suitable seedbed without unduly destroying the residue, planting through the mulch, and performing subsequent tillage or cultivation under the mulch. It also involves the use of such crops in the rotation as to supply an adequate amount of residue to protect the land if properly used.

There is a tendency for stubble-mulch farming to show to advantage during periods of low rainfall or during dry years. It is also of value in increasing the intake of water for erosion protection. The practice of stubble mulching seems to be better adapted to the Great Plains and to the drier parts of the Columbia River Basin than to more humid sections.

Plowing. Plowing is an art, and the ability to plow land well comes only by practice. Plowing is usually the first step in the preparation of the seedbed. In this operation the soil is loosened, the vegetable material on the surface is turned under, and there is a more or less complete inversion of the soil, which brings about pulverization. If these objects are to be satisfactorily accomplished, the soil should not be too dry or too wet when the plowing is done. If soil is too dry when plowed, it is likely to break cloddy, and the amount of pulverization will be reduced. A soil plowed when too wet is likely to be greatly injured on account of the puddling or breaking down of the soil granules.

Plowing is one of the most important steps in seedbed preparation, and, if properly done, much labor is saved later on. In well-plowed land the entire furrow is cut and turned; the plowing is usually from 5 to 7 inches deep, or sufficiently deep to allow thorough pulverization of the soil; the organic material turned under is well covered with soil; and usually the furrows are straight.

Depth of Plowing. It seems that extremely deep plowing is not necessary for the ordinary field crops. Deep plowing does not necessarily decrease the yield, but the increase, if any, is often slight and not sufficient to pay the extra expense incurred in the operation. Under ordinary conditions with the common field crops, a desirable and practicable depth to plow seems to be about 5 to 8 inches. However, the depth to which land should be plowed will frequently vary somewhat with the time of plowing and kind of soil. In the late fall and winter, when the land is to be planted in the spring, the plowing may frequently be deeper than when land is to be planted soon after plowing.

Especially is this true in case of heavy soils, such as clays and clay loams, when some of the subsoil is brought to the surface, as the freezing and thawing will aid in the disintegration of the exposed subsoil.

Sewell[10] reports that plowing deeper than 7 inches does not generally result in increased crop yields.

Time of Plowing. The time when plowing should be done will vary with the climate, crop, and soil conditions. In the drier sections of the country the land should be plowed and kept prepared for as long a time as possible before the crop is planted. In the humid sections the time of plowing will depend on the crop and conditions of the soil. In the case of such crops as wheat, rye, oats, and barley, when fall-sown, the plowing should be done in the summer. The plowing of land for corn, cotton, oats, barley, cowpeas, soybeans, and other spring-sown crops may be done in the fall or the spring. Sod lands and heavy soils, such as clays and clay loams, which are to be planted in the spring should be plowed in the fall or winter, and the seedbed further prepared in the spring.

Examples. The importance of the time of plowing may be shown by the results of several experiments.

Zook[11] secured 14.7 bushels of winter wheat per acre for late plowing in Nebraska, and 20.4 bushels for early plowing followed by clean tillage. The increase obtained for early plowing resulted from the conservation of moisture through weed control.

Results reported by Gray[9] from experiments in Iowa, regarding seedbed preparation for corn, showed, that

> Methods involving a minimum amount of work on the soil resulted in about 25 per cent decrease in yield. On fall plowing the best yields were obtained on plots that were covered three times with tandem disk and spike-tooth harrow—about twice as much work as ordinarily done by farmers in preparing a seedbed. On spring plowing, a single coverage with tandem disk and spike-tooth harrow produced equally as good yields as a larger amount of work. Results emphasize the importance of having the soil entirely free of weed growth at the time of planting.

So far as crop yields are concerned, fall or spring plowing is of about equal value under most conditions. Some factors other than yield of crop should be the guiding consideration in determining whether land shall be plowed in the fall or the spring.

Fall Plowing. There are certain conditions that make late fall and winter plowing especially desirable. At this time there is no special rush of other work; organic matter can be turned under and given time to decay; the soil has a chance to settle; the freezing and thawing characteristic of the season improve the structure of the soil; plant nutrients become more available; many perennial plant roots and insects and their eggs are destroyed by being disturbed and exposed to the cold; and in the fall the land may be plowed without injury when it is much wetter or drier than in the spring.

Fall plowing may start any time after the weather becomes cold. It

is not a good plan to plow land in the fall while nitrification is likely to be active. Plowing the soil makes conditions especially favorable for this process; and as no crop is growing on the land, much of the nitrates may be lost. There is but little nitrification taking place in the late fall and winter, and but small amounts of nitrates will be formed before spring.

It is not always desirable or advisable to plow land in the fall. Usually soils very poor in organic matter should not be plowed at this season, as such soils tend to run together instead of becoming granular. Also, in regions of high winds the loose, open soils, poor in organic matter, are likely to blow badly. Where practicable, it is better to plant such lands in cover crops in the fall and plow them in the spring.

Land plowed in the fall or winter should be left rough until spring, when it should be harrowed and put in condition for planting. Land left rough during the winter catches and holds more of the snowfall and retains the rainfall more effectively.

Spring Plowing. Much plowing must necessarily be done in the spring. When land is plowed at this time, more work is required to get it into condition for planting than in the case of land plowed in the fall. It has not had the chance to settle, the organic matter has not had opportunity to decay, and the soil is not so well granulated as soil that has been plowed and exposed to the freezing and thawing of the winter. Thus in the case of spring-plowed land many of the desirable characteristics of the seedbed can be secured only through tillage, whereas with fall-plowed land some of these characteristics are developed through natural processes.

Deep Tilling, Subsoiling, and Dynamiting. The results of some experiments show that the practice of deep tilling, subsoiling, and dynamiting is profitable. However, most of the experimental results do not show this to be the case. It seems probable that the practices of deep tilling, subsoiling, and dynamiting are not advisable for the ordinary crops grown under the conditions that generally prevail.

Benefits of Good Preparation. The beneficial effects secured through preparation of the land for seeding are the following: (1) conservation of moisture, (2) destruction of weeds, (3) better aeration of the soil, (4) utilizing the organic material to the best advantage, (5) pulverizing and loosening the soil, and (6) compacting the soil.

Conservation of Moisture. The conservation of moisture is especially important in the dry-land sections of the country. In such sections the rainfall of one season is often insufficient to produce the crop. However, if the land is kept in fallow one year, a crop can be grown the following year. As a result of fallowing, much of the rainfall is stored in the soil, and this moisture, with the rains of the growing season, may be sufficient

for producing the crop. Not only is the preparation of the seedbed important from a moisture-conservation standpoint where dry farming is followed, but in humid sections the same principle applies. In the latter sections rainfall is often scant during parts of the growing season, and the plants draw heavily upon the water previously stored in the soil.

Killing Weeds. Weeds use large quantities of water and plant nutrients, and in many instances the killing of weeds may be the chief factor in moisture conservation. The loss of moisture and plant nutrients by the growth of weeds is discussed in Chap. XVII.

Aeration of the Soil. In a well-prepared seedbed conditions are favorable for the plant nutrients to become available to plants. This fact may be due largely to the thorough aeration of the soil, since air is necessary for some of the chemical and biological activities in the soil. In the preparation of the seedbed, the soil is exposed to the air, and as a result the inert plant nutrients become more available through such processes as oxidation and carbonation, oxygen also being furnished for the formation of nitrates. Thus through tillage the soil air is modified and diffused, and as a result more nitrates are formed and more plant nutrients liberated.

Utilizing Organic Matter. The incorporation of organic matter in the soil, or leaving it on the surface as in stubble-mulch farming, is necessary for continual high yields of crops. In a well-worked seedbed the organic materials that may have been grown on, or added to the soil, or both, are completely turned under or left on the surface. Such materials add organic matter and a certain amount of plant nutrients; increase the number of organisms in the soil; supply nutrition for them; usually increase the water-holding capacity of the soil; and improve its structure.

Pulverizing and Loosening the Soil. Soils, especially if clayey, tend to become too compact for crops to grow well. This condition is true notwithstanding the fact that soil organisms and the action of the roots of plants tend to keep the soil loose and open. If large yields of crops are to be obtained, therefore, it is necessary to prepare the ground in such a way as to pulverize and loosen the soil. In the preparation of the seedbed the land is stirred, pulverized, loosened, and inverted, usually by plowing, disking, rolling, and harrowing—the object of the processes being to secure a desirable structure. If the land is properly worked, a crumb condition of the soil particles is developed, in which condition the soil contains a higher percentage of its plant nutrients and moisture in an available state, allows ready access and movement of air, permits easy penetration of roots, and is most favorable for the activities of the various soil organisms.

After the land has first been plowed, if best results are to be obtained,

it is necessary with practically all crops to have a firm, compact seedbed properly mulched on the surface. A thorough firming of the soil allows free movement of water by capillary action, brings the furrow slice and subsoil in intimate contact, produces a desirable structure, and aids in the control of soil temperature and air.

Some Characteristics of a Good Seedbed. It is not feasible to attempt to give a discussion of the preparation of the seedbed for the various crops. However, there are certain conditions that hold for all crops. The seedbed is the place where the seeds germinate and the medium from which the resulting plants, through their roots, secure moisture and mineral nutrients. It is desirable, therefore, that the seedbed be in such a condition as to furnish an abundance of moisture, nutrients, and air and to allow full penetration of the plant roots.

The best time to prepare the seedbed is before the crop is planted. Too many farmers prepare the seedbed improperly, especially for intertilled crops, with the expectation of overcoming by the cultivation of the crop the deficiency in seedbed preparation. A well-prepared seedbed is firm and compact beneath, loose and open on the surface, and free from clods. Land in this condition warms readily and holds a large percentage of its water and plant nutrients in an available form. Moreover, the water and air movements are free, and, other things being equal, the plants grow well and make good yields.

It is clear that the seedbed should be well prepared before the seed is planted. In many cases a good indication of a well-prepared seedbed is the absence of clods. Land that has been plowed at the proper time and thoroughly tilled is practically free from clods. Crops do not grow well on cloddy land, as the clods retain quantities of plant nutrients moisture, and bacteria that would otherwise be of benefit to the crops

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Topics for Discussion

1. What are the principal reasons for plowing and cultivating land?

2. Why have subsoil plows lost popularity for the United States as a whole?

3. What is the logic in first plowing land and then compacting it?

4. Since bare lands lose much plant food from leaching during the winter, why should fall plowing for spring crops ever be practiced?

5. Will stubble-mulch farming be found increasingly practical over widespread areas?

CHAPTER XI

SEEDING PRACTICES

The term "seeding" as used here refers to all methods of planting regardless of whether the crop is reproduced by seed or by vegetative parts. Most of the field crops, such as corn, wheat, and oats, are propagated from seeds, whereas others, such as potatoes, sugar cane, and some of the grasses, are propagated from vegetative parts.

Relation of Seeding Practices to Kind of Seeds. It is a well-known fact that seeding practices vary with the kind of crop. Generally speaking, grasses, clovers, alfalfa, and the small grains are seeded broadcast or in closely spaced drill rows. Corn, potatoes, cotton, tobacco, beans, sorghum, and all other crops that require intertillage are planted in rows far enough apart to admit the passage of ordinary tillage implements, or even wider, if the growth of the plants makes it necessary. There are, however, some exceptions to this rule.

Plant breeders and other workers who desire rapidly to increase the progeny of a new strain often sow small grains in rows sufficiently far apart to admit of cultivation. The practice of sowing oats in rows wide enough for subsequent cultivation has been practiced to a limited extent in certain parts of the South, but the method is not generally followed in any locality and seems to be waning in popularity.

Relation of Seeding Practices to Kind of Vegetative Parts. Bermuda grass may be propagated from seed, but the common practice is to plant root cuttings or pieces of sod. The latter method is surer and more satisfactory where conditions are not favorable for the production of seedlings.

Sugar cane is planted by laying stalks in furrows and covering them with soil. Shoots that develop into canes are put out at each joint. Certain crops that can be transplanted easily are often started in plant beds and afterward set in the field. Tobacco, tomatoes, and cabbage are good examples of this group.

Sweet potatoes are usually propagated by planting the roots close together in a hotbed and, when the shoots are large enough, drawing out the plants for setting in the field. In sections where the season is long enough, cuttings made from the plants that were grown in the hotbed are used to plant additional acreage. The crop grown from these cuttings

is recommended for seed purposes as the cuttings may be taken from healthy plants. Potatoes and Jerusalem artichokes are propagated from tuber cuttings.

Relation of Seeding Practices to Quality of Seeds. When seeds of poor quality are used, it is usually advisable to increase the rate of seeding in order to ensure good stands. If germination is low, a sufficient

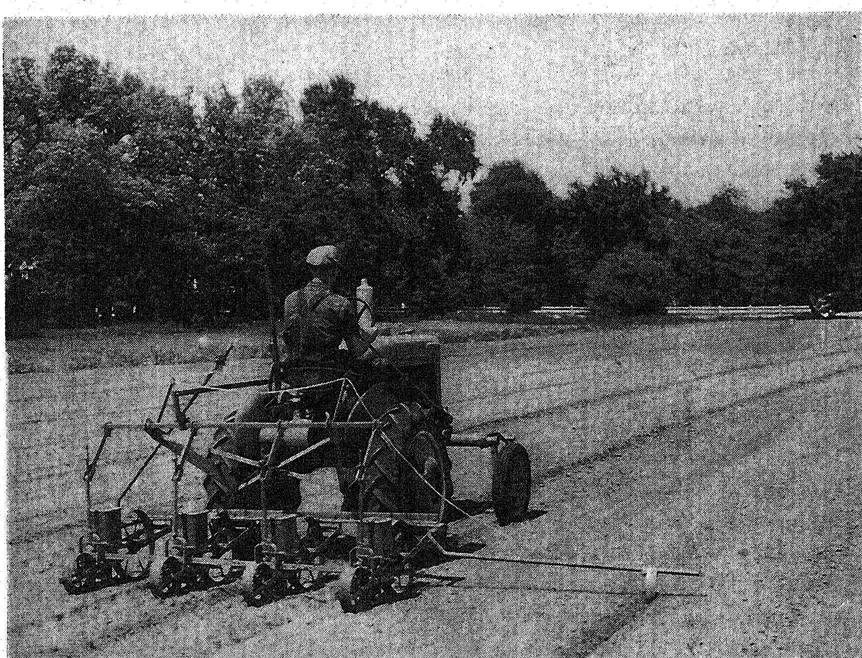

FIG. 13. A row crop being planted the easy way. (*Courtesy of American Iron and Steel Institute.*)

quantity should be seeded to ensure the proper amount of viable seed to the acre. If seeds that will germinate but are otherwise low in quality are sown, enough seed should be seeded to allow for the thinning out of the poorer plants, either by hand or by natural selection.

When large and plump seeds are sown in competition with smaller, poorly developed seeds there is a tendency for the progeny of the inferior seeds to be eliminated. This is particularly striking where seedings are thick. Thus when seeds of poor quality are sown thickly, the weaker plants will be crowded out. However, inferior seeds should not be used if this can be avoided, for even when sown thickly, uneven stands may be obtained.

As a general rule, a bushel of properly graded and treated hybrid seed corn will plant more acres of land than will a bushel of the usual open-

pollinated seed corn. The hybrid seed corn can be dropped from the planter accurately and uniformly. The treatment given the seed aids in controlling seed-borne diseases, and it practically always shows a high percentage of germination. Thus, not so many kernels of hybrid corn are necessary to ensure a stand of the same number of stalks per acre. In comparing the seed cost of open-pollinated and hybrid corn, it should be done on the basis of the cost of seed required to plant an acre rather than on the cost per bushel.

Relation of Seeding Practices to Climate and Season. Generally speaking, the hardier strains and varieties of crops give best results in rigorous climates. It has been found that clover seeds imported from southern Europe produce plants that are not nearly so resistant to winterkilling in the northern part of the United States as native-grown strains. The introduction of Grimm alfalfa, a very cold-resistant variety, into Minnesota and the Dakotas has made it possible to grow alfalfa successfully in many sections where other kinds were very uncertain. Cold-resistant varieties of wheat that have greatly increased the area over which winter wheats may be grown have also been developed.

The amount of rainfall has an important bearing on the depth of seeding. In sections where rainfall is heavy, most crops should be seeded comparatively shallow, as when seeds are sown deep in such sections the soil surrounding the seeds may remain saturated with water long enough to interfere with proper germination. In dry sections, however, it is necessary to place the seeds deep enough to bring them in contact with the soil moisture. The climate and season also have an important bearing on the rate of seeding. When fall-seeded grains are sown in sections where winters are severe, it is necessary to sow more seed to the acre than is the case where winters are mild. In the southern part of the winter wheat belt, 4 to 6 pecks of wheat to the acre give satisfactory results, whereas in the northern part of this belt 8 to 10 pecks to the acre are commonly sown. In like manner, 1 to 2 bushels of winter oats to the acre give satisfactory results in the southern part of the winter oats belt, whereas in the northern part of this area 3 to 4 bushels must be sown to the acre for best results. In the milder sections tillering of the plants is more pronounced, and the stand from thin seeding is thus thickened. In the colder sections winterkilling is common, and enough seed must be sown to allow for partial winterkilling and still have enough plants left for a sufficient stand. Then, too, when winter grains are seeded thickly the crowded plants serve as a protection for one another. In sections where the nature of the soil commonly causes crusting or baking of the land after heavy showers, it is often hard to secure good stands

of such crops as soybeans and cowpeas. In these crops the cotyledons are pushed through the surface after germination has taken place, and if a crust has been formed on the surface many of them are broken off. Where such showers are common, these crops should be planted just deep enough to be thoroughly covered, and it is better to leave the seedbed loose on top rather than compact.

Relation of Seeding Practices to Time of Seeding. The time of seeding has an important bearing on both the rate of seeding and the amount of fertilizer to use on winter wheat. When seeding has been delayed beyond the best seeding date for the section it is a common practice among farmers to sow an unusually large quantity of wheat to the acre.

There is a strong relation between the kind of fertilizers used and the amount of winterkilling in wheat. For example, wheat on soils made productive by the use of liberal applications of the right kind of fertilizers resists winterkilling much better than wheat on unproductive soil. This result is to be expected, as wheat usually starts more rapidly on productive soils and acquires a better root system before severe weather sets in. This would suggest that it is very important to see that growing conditions are right when small grains subject to winterkilling are seeded late.

The method of seeding certain crops varies in certain sections according to the time of seeding. In the sections of the South where early potatoes are planted for the summer market, it is a common practice to ridge the land and plant potatoes on these ridges above the general level of the field. In the same section the late crop of potatoes is planted 3 to 6 inches below the level of the field. Where corn is planted very early in the season, while the ground is still cold and wet, it should be planted very shallow. Later plantings may be planted deeper. In cases where dry weather is likely to occur soon after planting, it may be advisable to list the land or to open furrows 4 to 6 inches deep, plant the corn in the bottom of the furrows, and cover 2 to 3 inches deep.

Relation of Soil Productivity to Rate of Seeding. As a rule, since tillering is greater on productive soils and since the increase in number of tillers makes up for the thinner seeding, small grains are seeded at a heavier rate on thin soils than on the more productive soils. Hickman,[1] in Ohio, recommends 8 to 9 pecks of wheat per acre on the poor soils of Ohio and 5 to 6 pecks on the rich soils.

Hutcheson and Wolfe,[2] in Virginia, found that on soils capable of producing 15 to 25 bushels to the acre, seeding 6 pecks of wheat to the acre gave a larger yield than smaller quantities, while on soils capable of

producing 20 to 35 bushels to the acre, 4 pecks of seed produced greater yields than either larger or smaller quantities.

In the case of intertilled crops such as corn, potatoes, and tobacco the plants may be left thicker on rich soils than on poor soils. These crops do not tiller to any appreciable extent, and therefore must be planted at the rates that will utilize the plant nutrients of the soil most economically. Mooers[3] found that in Tennessee, on soil with an expectancy of 20 or 25 bushels to the acre in a fair season, 3,000 stalks of corn to the acre gave highest yields, whereas on soil capable of producing 60 or 70 bushels per acre in a fair season, maximum yields were obtained from 7,000 stalks to the acre. Mooers[3] also found that different varieties of corn require appreciably different rates of planting. In general, the small and short-season varieties required thicker planting than the larger, long-season varieties.

Relation of Soil Moisture to Method of Seeding. Too much moisture in the soil usually retards germination and induces rotting of seed in the ground. Rice may be considered an exception. On the other hand, all seeds require moisture for germination, and plants require water for growth. For this reason different methods of seeding are practiced in soils of different moisture conditions at planting time. In those sections of the country where rainfall is likely to be abundant at planting time, corn and other cultivated crops are planted just deep enough to ensure germination. Usually the fields are made as level as practicable, and the seed is placed just below the surface of the soil. In sections where soil moisture is likely to be low at planting time and during the early stages of growth, listing is often practiced, especially with corn. The term "listing" as used here should not be confused with the practice of throwing two furrows together and planting on the ridge so formed, sometimes called listing in parts of the South. Listing in the true sense consists in opening a furrow several inches deep by means of an implement with a double moldboard, and depositing the seed about 2 inches below the bottom of the furrow. This method of planting corn is in common use in semiarid regions. The advantages of the practice are that the seed is deposited in a moist area and that the roots of the corn, being deeper than those of surface-planted corn, suffer less from drought and heavy wind.

Where drainage is poor, crops are often planted on ridges or beds. These ridges may be wide enough for several rows, or there may be a ridge for each row. When crops are planted on ridges, the seed is usually planted above the general level of the surface of the field and the furrows between the ridges act as drains; thus it is improbable that the area immediately around the seed will become saturated. This method is

in common use on river bottoms subject to overflow and on other lands that are likely to be wet and cold during the early period of plant growth.

Relation of Topography and Weeds to Method of Seeding. Much has been written concerning the relative value of planting crops, particularly corn, in drills that allow for cultivation only one way, and in check rows that allow for cultivation both ways. The evidence on this point is somewhat conflicting, but the difference in favor of one method over the other is usually not very great. The most commonly accepted belief is that yields will be practically equal under both methods if the fields are kept equally free of weeds and the same number of plants left to the acre. Where the topography of the fields is rolling and the land is subject to erosion, drill rows following the contour lines of the fields will be found more satisfactory. If crops are planted in check rows on rolling land, the cultivation up and down the hill will favor erosion. On comparatively level land there is no choice between the two methods unless weed pests are serious. In the case of very weedy land, checking usually pays, as it allows for cultivation both ways and facilitates weed destruction. Mooers[3] has found that corn rows just wide enough for easy passage of cultivating implements with the required number of plants evenly distributed in the rows give better results than very wide rows with the plants thickly planted in the rows.

Relation of Seeding Practices to Crop Use. In certain crops the use to which the crop is to be put governs the seeding practice. The soybean crop serves well to illustrate this point. If soybeans are grown for hay, they are commonly seeded thickly just as small grains are sown. If the crop is to be harvested for seed, it is usually desirable to seed in drills wide enough apart to admit of cultivation, though the thick seeding method may be used. However, seed yields are slightly greater from soybeans seeded in rows rather far apart. Then, too, the soybeans sown in rows have fewer weeds and are easier to harvest. Where the soybeans are threshed from the standing stalks in the field, they must be planted in rather wide rows to prevent injury during harvest. Only about half as much seed is required for seeding in rows as is required for seeding thickly. However, the expense of cultivating the plants in wide rows will usually equal that of the extra seed required for sowing thickly; consequently, there is no economy in row seeding when soybeans are intended for hay. If soybeans are to be used with corn for silage or for hogging down, they may be planted in the same row with the corn. There are machines on the market that will plant the two crops in alternate hills and thus ensure an even distribution of both crops.

When corn is to be used for making silage it is generally planted

thicker than when grown for grain. Sorgo for hay is usually seeded broadcast, whereas if it is to be used for making sirup it ordinarily is seeded in rows far enough apart to cultivate.

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Topics for Discussion

1. Is it better to sow seed in dry soil or to wait until after a rain?
2. Should seedings be thinner or thicker on poor soils?
3. Why is it desirable to compact most soils before sowing small seed?
4. Should corn be planted deeper in hot weather or vice versa? Why?

CHAPTER XII

TILLAGE

Tillage may be defined as the practice of working the soil for the purpose of bringing about more favorable conditions for plant growth. All operations that affect the soil, such as stirring, fining, firming, and inverting, are included in tillage. Tillage is costly but necessary in the production of crops. Gray[1] states that approximately one-third of the cost of producting cotton consists of seedbed preparation, planting, cultivating, and hoeing. The most common tillage operations are plowing, harrowing, rolling, and cultivating. The last operation will be discussed in this chapter.

Classes of Crops Based on Tillage. Crops may be divided, in so far as tillage is concerned, into intertilled, and drilled or broadcast. The former are sown or planted in rows at least far enough apart to allow cultivation to be readily practiced. In the intertilled class are found such crops as corn and sugar beets. The drilled or broadcast crops are usually seeded broadcast, either by hand or by machinery. If crops are broadcast by hand, the seeds are scattered indiscriminately over the land, but, when seeded by machinery, they are placed in rows that are usually close together. Some commonly drilled or broadcast crops are wheat, oats, rye, and barley. The same crop may fall in either class according to the method of seeding. Such crops as soybeans and cowpeas are illustrations.

Development of Tillage Practices. Jethro Tull is considered the father of modern tillage. In 1731 Tull published his book on "Horsehoeing Husbandry," in which was set forth a theory of tillage. According to Tull "tillage is manure," and the advantage resulting from cultivation was a freeing of the soil particles. He believed that earth was the only food for plants and that the plants fed from the minute particles of soil that were secured from around the soil grains; therefore, the more finely divided the soil, the better would the plant be nourished. It was believed that the chief benefit derived from the application of manure was that it pulverized the soil.

In the beginning of the nineteenth century the science of agricultural chemistry was developed through the work of Priestley, Liebig, and others. At this time the conception of the nutrition of plants based on

the assimilation of chemical elements from soil minerals, organic matter, water, and air was evolved. With the development of this idea of nutrition of plants the reason given for tillage of the soil was that it increased the aeration and thereby increased the oxidation of chemical compounds in the soil and made them more available for plant use.

Gaylord[2] stated that tillage was important in that it thoroughly stirred and mixed soil and enabled the grower to change the relation of the soil in regard to moisture, temperature, and plant nutrients. Goodale[3] thought deep tillage and subsoiling were important in that roots were allowed to penetrate deeply in the soil for nutrients and water. Turner[4] thought the real purpose of plowing was to put the soil into such condition that the plant could more readily absorb energy, take up moisture, and assimilate nourishment from the air and soil. According to Sweet,[5] the chief benefit to be derived from cultivation was the control of weeds. Johnson[6] emphasized the importance of cultivation in loosening the soil, benefiting chemical reactions, and improving moisture storage conditions and the structure of the soil. Davenport[7] stated that cultivation is done primarily to pulverize and stir the surface of the soil, when it becomes hardened and baked by rains. As a result the soil is more retentive of moisture, and crops suffer less from drought.

The present indications are that the primary reason for the cultivation of crops is to control weeds. In fact, Richey[8] states, "The results of all the experiments considered as a whole indicate that cultivating as often and as deep as necessary to control weeds, and no more, is the desirable practice."

EFFECTS OF TILLAGE

Crops are usually cultivated because cultivation increases the yields. The yields are increased on account of certain beneficial effects of the tillage operation on the soil and crop. Some of the ways in which cultivation of crops increases yields are as follows: (1) destruction of weeds, (2) conservation and storing of moisture, and (3) aeration of the soil.

Killing of Weeds. The destruction of weeds is usually the most important consideration in the cultivation of crops. Not only do weeds use plant nutrients and moisture that might otherwise be available to crops, but they may also cause injury to the crops by shading. Many experiments have been conducted that show the great benefit to be derived from cultivation through the destruction of weeds.

Mosier and Gustafson,[9] in Illinois, found the 9-year average yield per acre of corn from the plat on which the weeds were removed with the hoe to be 48.9 bushels. When the weeds were allowed to grow, the yield was 7.5 bushels, or a difference of 41.4 bushels in favor of prevent-

ing the growth of weeds. In order to determine whether weeds reduced the yield of corn by depriving the plants of moisture, one of the plats on which the weeds were allowed to grow was irrigated. The fact that the irrigated plat yielded only 2.5 bushels more to the acre than the nonirrigated plat indicates that in this instance weeds did not materially reduce the yield of corn through the use of available moisture. However, irrigation increased the yields on cultivated plats 8.2 bushels per acre.

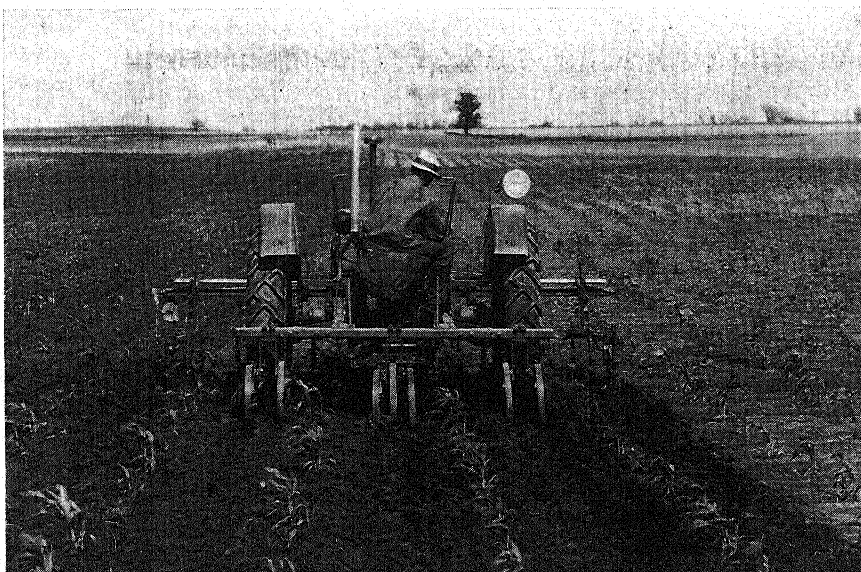

FIG. 14. Cultivating with a modern four-row steel implement. (*Courtesy of American Iron and Steel Institute.*)

Call and Sewell,[10] in Kansas, found that weeds remove a large amount of water and nitrates from the soil. The same investigators show that about as much nitrification takes place under weeds as under the mulched and bare-surface plats. Therefore, if the weeds are turned under, the succeeding crop should receive as much nitrogen as that planted on the bare and mulched plats. They found that large amounts of water and nitrogen used by weeds might otherwise be available for crops.

Conservation and Storing of Moisture. It is generally stated that cultivation conserves moisture by preventing evaporation from the surface of the soil and by enabling the plant to make more economical use of water. Cultivation increases the moisture supply by reducing surface runoff and by killing weeds. There is at the present time much discussion as to the value of cultivation in the prevention of loss of water by surface evaporation. Some investigators state that cultivation is

important from this standpoint, whereas others take the opposite view. It would seem, however, that cultivation should reduce loss by evaporation from the heavier types of soil, at least from those which are hard and baked on the surface and badly cracked.

Relation of Cultivation to Evaporation of Moisture. Call and Sewell[10] found that cultivation did not reduce the loss of water from the soil by evaporation. On the other hand, Thom and Holtz,[11] in Washington, found that land mulched 3 inches deep lost 0.55 inch of water, whereas land not cultivated lost 2.31 inches of water by evaporation. Knight,[12] at the Nevada Experiment Station, found that land cultivated 6 inches deep lost 27.8 per cent less water by evaporation than uncultivated land.

Relation of Cultivation to Use of Water by Plants. Plants growing on cultivated soil make more economical use of water than plants growing on uncultivated soil. In other words, plants that are cultivated use less water per unit of dry matter produced than plants not so treated. It is also well known that plants growing on rich soil make more economical use of water than plants produced on poor soils. Noyes[13] states that cultivated plants require less water in the production of dry matter than uncultivated ones, as cultivation increases the available plant nutrients in the soil. Widtsoe,[14] in Utah, states that "cultivation not only prevents direct evaporation of water from the soil but also reduces materially the amount of water that must be transpired by a plant for the production of a certain definite quantity of dry matter."

Many crops require from 300 to 500 pounds of water to produce each pound of dry matter.

Relation of Cultivation to Loss of Water by Surface Runoff. Cultivation helps to increase the supply of water by reducing surface runoff. The runoff is as a rule much greater from a smooth or uncultivated soil than from a rough or cultivated soil. Call and Sewell[10] found some interesting facts in this regard. On the dry basis on disked plats, the average percentage of moisture in the soil from Apr. 17 to Sept. 9, 1916, was as follows: weeds growing, 16.72 per cent; mulched 3 inches, 19.59 per cent; mulched 6 inches, 17.92 per cent; and not mulched (bare surface), 17.81 per cent.

Comer, Dickson, and Scoates,[15] in Texas, found that 33 per cent of the rainfall was lost in runoff water from cultivated fallow and 44 per cent was lost from fallow not cultivated.

Aeration of the Soil. It is usually necessary to have a well-aerated soil before the greatest and most favorable bacterial activities can take place. Air is also necessary for certain chemical and physical changes in the soil so important to plant growth in making plant nutrients more available and in improving the tilth of the soil. In addition to these

things air is usually necessary to the germination of seeds and growth of plants. However, this statement does not apply to such plants as rice. Cultivation stirs and turns the soil and in this way greatly increases the supply of air and keeps it agitated and well distributed.

Effect of Aeration on Availability of Plant Nutrients. The effect of aeration on the production of available plant nutrients in the soil is very important. Oxygen and carbon dioxide are necessary for certain chemical changes in the soil that make the inert plant nutrients available. Numerous experiments may be cited to show that cultivation does not increase the supply of available plant nutrients in the soil through better aeration. Such results may be explained on the basis that the soil contained sufficient air to bring about the chemical and biological changes. If a sufficient amount of air is present in proportion to the other factors present for carrying on the processes, a further increase in the supply of air will not increase the amount of the product produced. Gainey and Metzler,[16] in Kansas, found that nitrate accumulations were as great in a compact as in a loose soil, provided the moisture was not greater than two-thirds of saturation. This fact indicates that sufficient air for the nitrification process was present in the compact soil and that further aeration did not increase the amount of nitrate since oxygen was not limiting the production. Call and Sewell[17] state that cultivation does not cause an increase in the amount of nitrates accumulated, with the probable exception of heavy types of soil.

Lyon,[18] in New York, studied the effect of the aeration of soil on nitrates. Cultivated soil showed the highest nitrate content; scraped soil, intermediate; and soil mulched with straw, the lowest.

The results of experiments on the effect of cultivation on aeration indicate that on the heavier types of soil cultivation is beneficial in its effect on soil air, this being especially the case with soils that have a tendency to puddle and bake on the surface. However, in the more open types of soil, having only a slight tendency to bake and to form a crust on the surface, the beneficial effect of cultivation on aeration of the soil is less marked.

Tillage Practices with Intertilled Crops. There is abundant proof that the cultivation of the crops ordinarily intertilled is very profitable. There is, however, much difference of opinion as to the number of cultivations necessary for most profitable returns, the depth of tillage most desirable, and the best time at which the cultivations should be given. These things will vary with the kind of crop, the climate, and the type of soil.

Frequency of Cultivations. There is no reliable way of telling how frequently crops should be cultivated. The number of cultivations will

vary with conditions. It is necessary to cultivate more frequently in dry than in wet seasons. At the Illinois Station, Mosier and Gustafson[19] found that corn cultivated shallow four or five times yielded 81.7 bushels, whereas that cultivated shallow twelve to fourteen times yielded 82.2 bushels, based on a 3-year average. The small increase secured from the large number of cultivations is not sufficient to pay for the extra labor involved.

FIG. 15. Cultivating corn with a rotary hoe. Corn is about 18 inches high. (*U.S. Dept. Agr. photograph.*)

Since the number of cultivations most advisable seems to depend upon several factors, no definite recommendation can be made in this regard. However, it may be said for those crops commonly intertilled that the cultivations should usually be frequent enough to keep down weeds and to keep a soil mulch over the surface of the field.

Depth of Cultivation. For best results intertilled crops should practically always be given shallow cultivations. Cultivations that are too deep reduce the yield of crops. Shallow cultivation seems to be efficient in conserving water, aerating the soil, and killing weeds. Cultivation should be no deeper than is required to kill weeds.

Sanborn,[20] at the Utah Experiment Station, reported a yield of 186.7 bushels of potatoes from no cultivation, 206.38 bushels from shallow cultivation, and 204.87 bushels per acre from deep cultivation. Similar results were also reported by Kiesselbach and others[21] in Nebraska. At the Ohio Experiment Station, Williams[22] found the 9-year average yield of corn from deep cultivation (4 inches) to be 56.4 bushels per acre. The yield from shallow cultivation ($1\frac{1}{2}$ inches) was 60.4 bushels, a difference of 4 bushels in favor of shallow cultivation. Mosier and

Gustafson[19] in Illinois, reported the results of root pruning and cultivation of corn as shown in Table 8.

TABLE 8. RESULTS OF CULTIVATION OF CORN AND ROOT PRUNING (AVERAGE 3 YEARS)

Kind of Cultivation	Yield, Bu. per Acre
None, weeds kept down by scraping with hoe	78.7
Shallow, 4 or 5 times	81.7
Deep, 4 or 5 times	73.3
Shallow, 12 or 14 times	82.2
Deep, 12 or 14 times	74.2
Roots unpruned, shallow, ordinary	88.8
Roots pruned, shallow, ordinary	74.7
Roots unpruned, weeds scraped off with hoe	85.5
Roots pruned with knife, weeds scraped off with hoe	71.8

Kiesselbach and others,[21] in Nebraska, found but little difference in yield of corn from shallow, medium, or deep cultivation.

Time of Cultivation. If in the cultivation of crops the aim is to keep all weeds destroyed and to keep the surface of the ground mulched, it is necessary to cultivate the land as soon after each rain as practicable. The time of cultivation and the number of cultivations a crop should receive will vary largely with the season.

Mulches. In the cultivation of crops a soil mulch is formed on the surface of the soil. The object of a mulch is to prevent the loss of water by evaporation. To be effective a mulch must be dry and reasonably fine. It is desirable to have a granular or soil mulch rather than a fine or dust mulch. The former breaks the capillary use of water more readily than the latter and is not so likely to form a crust after a shower.

Deep mulches are more effective in preventing loss by evaporation than are shallow mulches. However, the plant nutrients contained in the soil forming the mulch are not readily secured by plants. For this reason the land in which crops are growing should not be mulched too deep. As a general rule, land growing crops should be mulched about 2 inches deep.

Kinds of Mulches. Mulches are of two kinds—artificial and natural. All artificial mulches are formed by the application of some material, such as leaves, straw, and manure, to the surface of the land. The use of such mulches is rather limited. The natural mulches include soil and stubble mulches. The soil mulch is formed by stirring the surface of the soil and producing a loose, open condition. The stubble mulch is produced by tillage practices that leave the crop residue on the surface of the land (Duly and Mathews[23]). The soil mulch is by far the most common form and usually the most practical.

If a mulch is to be effective, it must be maintained. The difficulty in maintaining the soil mulch depends largely on the type of soil. It is comparatively easy to maintain a mulch on soils that are high in organic matter and have a loose, open structure. The heavy soils that are low in organic matter and have a tendency to run together and to become cloddy on wetting are difficult to keep properly mulched. However, on very sandy soils mulching is of little value.

Wimer and Harland,[24] in Illinois, found that the 6-year average (1916–1921) yield of corn per acre where weeds were allowed to grow was 7 bushels; weeds scraped with hoe, 53.3 bushels; cultivated with blades 1 to 1½ inches deep, 53 bushels; and cultivated with shovels 2 to 3 inches deep, 51.1 bushels.

Cates and Cox[25] state that "Cultivation is not beneficial to the corn plant except in so far as removing the weeds is concerned." The results of the experiments conducted by the investigators south of the latitude of Washington, D. C., show an increase in yield of 2.1 bushels of corn per acre for cultivation.

Hundreds of tests have been conducted in which there were compared the yield of corn from cultivated acres and the yield from those from which the weeds had been removed by disturbing the soil but little. In most experiments the differences in yields have been negligible. In a few cases, however, cultivating gave much better results, and in a few cases scraping the weeds resulted in better yields.

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Topics for Discussion

1. To what extent does tillage conserve moisture?

2. Which makes the best soil mulch, an implement that thoroughly pulverizes the topsoil or one that leaves it in larger lumps?

3. How would an implement that cultivates to the depth of 3 inches, used weekly, affect the amount of plant food available to an intertilled crop?

4. Is tillage of sod crops and alfalfa practicable?

CHAPTER XIII

HARVESTING AND STORAGE OF GRAIN CROPS

It is evidently important to harvest a crop at the time that will allow the greatest yield and at the same time ensure a product of high quality. It is useless to go to the expense of producing a crop and to allow all or a part of it to waste because of untimely harvesting. Often inopportune harvesting cannot be avoided, but too frequently great neglect is shown at this stage of crop production. In case of a large acreage of the same crop and extremely favorable conditions for ripening, the crop frequently begins to deteriorate before harvesting is completed. On the other hand, crops are sometimes harvested before the optimum condition is reached. These two extremes should be avoided in so far as practicable. Therefore, in so far as the time of harvesting is concerned, losses may be due to harvesting too early or too late.

The problem of storage of grain crops, together with the factors affecting this problem, is also of great importance.

Losses from Delayed Harvesting. In case of the small grains the chief causes of loss from harvesting crops too late are (1) shattering of the grain and (2) lodging or falling down of the plants.

With the corn crop the main loss is from the wasting and the deterioration of the blades. This loss is not always serious, as the stalks are sometimes left in the field after the ears have been pulled. In some sections this loss is more serious, as the forage of the corn plant is an important source of feed for livestock, and the leaves constitute the most nutritious part of the forage. However, about 85 per cent of the corn crop, including grain, is used for forage.

In the case of the small grains the loss from shattering varies with the variety, the number of times the unthreshed grain is handled, and the weather conditions. Some varieties of wheat retain the grain much better than others. The more often the unthreshed grain is handled, the greater the loss from shattering. Under continuous dry weather small grains are likely to shatter less than where dry and wet periods alternate.

The loss from lodging of grain crops from delayed harvesting is not so great as the loss that occurs when grain lodges before maturity. Lodged plants are more difficult to harvest, and in many cases not all the grain can be obtained. Also the damage from wet weather is usually greater in the

case of lodged grain than in the case of that standing erect. The grain of lodged plants develops but little, if any, after lodging takes place. Therefore, the loss is often severe when grain plants lodge early. This loss in development of the grain does not occur in the case of plants lodging from delayed harvesting.

In addition to the losses enumerated above, there is a loss due to the decrease in dry matter. This loss is a result of respiration, in which certain gases are produced and lost. Kiesselbach,[1] in Nebraska, found that wheat had its maximum amount of dry matter 2 days before it was mature. Arny and Sun,[2] in Minnesota, found the greatest percentage of dry matter in wheat and in oats 1 day before maturity.

Burnett and Bakke,[3] in Iowa, found in studying the effect of delayed harvesting upon the yield of wheat, oats, and barley that the duration of the harvest period depended on three factors: (1) soil and other cultural influences, (2) climate, which influences the development of the kernels and yield losses, and (3) the variety used.

Losses from Premature Harvesting. The losses resulting from harvesting immature grain crops are shown by smaller yields and by reduction in quality. The small yields are due to failure of the grain to develop fully, and to shrinkage subsequent to harvesting. The weight of grain produced increases until maturity is reached. Thus, if the crop is cut much before maturity, a considerably smaller yield is likely to result. There is also a greater shrinkage loss from green grain than from that cut at the proper stage. This loss is often considerable in the case of grain harvested when very immature, as shown by the badly shriveled condition of the kernels.

Quality is often as important in grain production as is the quantity produced. The quality of immature grain is reduced by the extremely shriveled condition of the grain. In addition, green grain is more likely to be damaged by heating and molding both in the field and in storage than ripe grain.

Cardon[4] found, at Nephi, Utah, that wheat cut in the green dough stage yielded 4 bushels per acre less than wheat harvested in the hard dough stage. Kiesselbach[1] secured results showing that the 4-year average yield of wheat increased from 21.5 bushels per acre at the milk stage to 34.6 bushels when mature.

The Proper Stage for Harvesting. A crop should be harvested at the time when the product will give the largest yield of the highest quality. The length of time during which a crop will remain just at the proper stage for harvesting varies with the season and kind of plant.

It can be readily realized that when a large acreage of a crop is grown, it is often not practicable to cut the entire crop at the ideal stage. The

harvest often begins when the crop is somewhat green and is not finished until after the crop has matured. The object is to begin soon enough so as to harvest the largest part of the crop at the ideal stage. Thus, in the discussion of the proper stage for harvesting any particular crop, the difficulties due to acreage, weather, and methods of harvesting must be kept in mind. It may often be impossible to cut the entire crop at the proper stage.

The increasing use of mechanical harvesters has made necessary a somewhat different consideration of the proper harvesting stages com-

Fig. 16. Harvesting wheat with a tractor-drawn grain binder. The bundles are to be shocked and later threshed, either from the field or after stacking.

pared with that when hand labor was more widely used. In the development of new varieties, yield, quality, and resistance to diseases and insect pests are still the main considerations, but more and more thought is being given to plant characteristics that make harvesting with mechanical equipment easier. An example is the development of the combine varieties of sorghum, such as Wheatland, Plainsman, Martin, and Beaver. In developing corn hybrids the ease of harvesting with mechanical pickers is being given important consideration.

Corn. Husking with mechanical pickers or by hand from standing stalks is usually started as soon as the corn is dry enough to store in cribs. Frequently the first corn husked is placed in several cribs to facilitate drying. An early frost or a dry fall makes it practical to start husking at an earlier date than when the fall is late or wet. Machine husking can be started some 10 days earlier than hand husking because of better removal of silks by machine husking.

When corn is to be harvested by hand for grain and stover, and placed in shocks, harvesting should start when the kernels are nearly all

well glazed and, in dent corns, beginning to dent; the husks and bottom leaves dry; and the upper leaves about one-fourth to one-half green.

Corn is ready to cut for silage when the kernels are well glazed, at which stage the husks begin to turn yellow. At this time the grain is in the late dough stage, which is attained about 1 week before corn is ready to cut for grain and stover.

Wheat. In harvesting wheat with combines, starting time is based mainly on the moisture content of the grain. At a week or 10 days

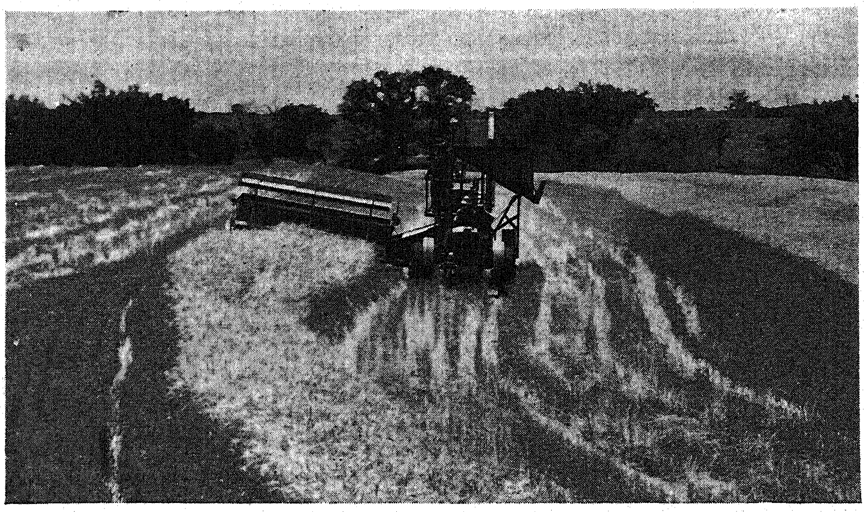

FIG. 17. Combining wheat on the crest of a terrace. (*U.S. Dept. Agr. photograph.*)

before wheat is ripe the kernels may contain as much as 50 per cent moisture; at binder harvest time, 30 per cent or more of moisture. Wheat is ready for harvesting with binders a week or 10 days before it is ready for combining. At combining time the kernels should be low in moisture for safe storage—13 or 14 per cent.

Hurst and Humphries[5] suggest this test for the degree of dryness:

Hold the center stem of the wheat head close to the base of the head with one hand and force the tip end of the head against the palm of the other hand and rotate vigorously. If about two-thirds of the sampled heads break, the moisture content is approximately right. If the wheat is damp the head is rarely broken during this simple hand test.

The proper stage of development for harvesting wheat when cut with a binder is the dough stage. At that time the straw is beginning to turn yellow and the grain is soft enough to be readily dented by the thumb nail but not soft enough to be crushed between the fingers. There seems to be a continuous increase in yield until the grain reaches maturity. The most rapid increase apparently comes just before the dough stage,

i.e., when the grain can easily be crushed between the fingers. Therefore, wheat cut much before the dough stage will give a low yield of grain that will be shriveled, off color, and of inferior quality.

Oats. Oats do not survive delayed harvesting as well as wheat, and, therefore, when there is a large acreage to harvest, it is well to windrow at least a part of the crop. When direct combining is done, the oats should be fully ripe. Ordinarily combining should begin when the straw shows no greenness and the heads have turned a dull white. When the crop is combined by the windrow method, harvesting should start about a week earlier, which is about the time it could be harvested with the binder and shocked. At that time the kernels are in the hard dough stage, and the heads are yellow in color. At this time almost one-half of the leaves are green, and, if the crop is shocked at once, the straw is comparatively palatable and nutritious.

If the oat crop is to be cured for hay, it should be cut when it is in the milk stage.

Barley. Barley in the humid region shatters to some extent when ripe. The barleys grown in the semiarid sections do not readily shatter. For direct combining, barley should have a moisture content not to exceed 13.5 per cent.

If barley is to be harvested with the binder it is usually done when the kernels are in the hard dough stage. At this time the straw is a yellow color and of good quality.

Rye. Rye should be harvested with the combine when the grain is dry enough for safe storage. The crop ripens several days earlier than wheat and shatters more readily and often matures less uniformly.

If the crop is harvested with a binder and shocked, it should be cut when the grain is in the dough stage.

Soybeans. The harvesting of soybeans depends somewhat on weather conditions. In hot dry weather, varieties that tend to shatter require greater care than those which do not, such as Biloxi, Manchu, and Mansoy. They can be left until dead ripe in almost any season with but little loss of seed.

All soybeans reach a definite size, depending upon variety and environment, and then mature and die. The leaves begin to turn yellow and drop when the plant approaches maturity and in most varieties fall off before the pods are fully mature.

If soybeans are harvested with the combine it should be done when the pods are mature, which will be about a week after they should be cut with the binder.

Sorghum. The heads of sorghum do not ripen uniformly. The grain at the top of the head ripens about a week earlier than that at the bottom.

Combining should not be done until the grain is dry enough for safe storage, at which time the moisture content should be 13 or 14 per cent. Hurst and Humphries[5] state that

> The moisture content can with experience be determined approximately by the "feel" of the grain, by crushing it between the teeth, or by denting it with the thumbnail. The moisture problem becomes unimportant when the grain is to be wetted and placed in silos to ferment like silage, as is being done on an increasing scale in southern Texas.

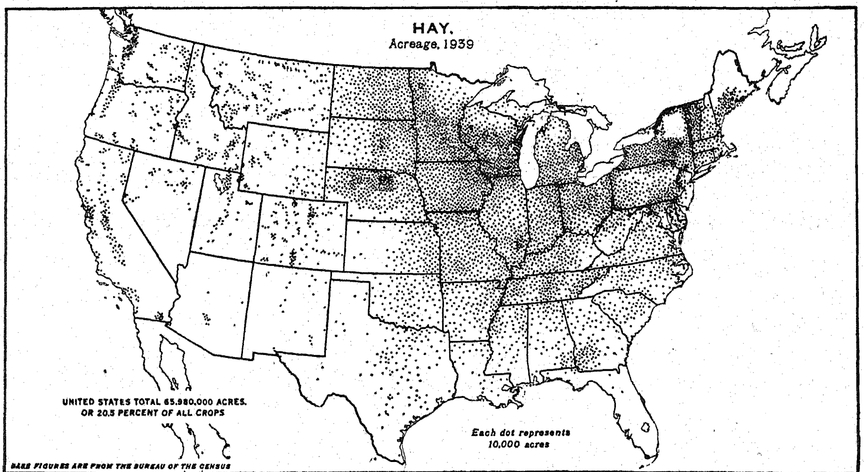

FIG. 18. The acreage of hay in 1939 extended throughout the United States and was more evenly distributed than ever before. This was probably due to the increase in 12 southern states of 4,256,000 acres, or about 75 per cent above 1929, whereas the remaining states had a decrease of 6,105,000 acres, or about 10 per cent. The total acreage of hay for 1939 was composed of clover or timothy hay, alone or mixed 26.2 per cent; sweet clover, 1.7 per cent; alfalfa, 19.4 per cent; wild hay, 18.1 per cent; all other tame hay, 11.0 per cent; lespedeza hay, 7.1 per cent; annual legumes saved for hay, 10.9 per cent; and small-grain hay, 5.6 per cent. Acreage devoted to hay sometimes can be diverted to other crops, but the addition of grass hay in cropping systems is not likely where it might compete with cash crops. In 1939 the three leading states in acreage of hay were Minnesota, 4,288,000 acres; Wisconsin, 3,395,000 acres; and New York, 3,661,000 acres. (*U.S. Dept. Agr., Bur. Agr. Econ.*)

Harvesting Methods for Different Grain Crops. The increasing use of mechanical equipment in harvesting grain crops has brought many changes in recent years. Only through its use can farmers afford to pay the high price demanded by labor and compete with industry for labor and make profitable returns in farming.

Combines. The combine is now widely used in practically all sections of the United States in harvesting grain crops and seeds of many other crops, such as alfalfa, clovers, lespedezas, and grasses. Silver and Sitterley[6] list the advantages of using a combine as follows: (1) lowers

harvesting costs, (2) reduces harvest labor, (3) makes one independent of exchange labor, (4) picks up down grain better than binder, (5) for the grain farmer, it spreads the straw, and (6) reduces cost and number of harvest meals. The disadvantages listed are (1) larger investment, (2) loss of straw, (3) difficulty in handling green material, and (4) uncertainty of weather.

Mayer and Bottum[7] found in Indiana that (1) grain from the combine was of as high quality as that from the binder and thresher, (2) the combine saved a higher percentage of grain, (3) when more than 20 acres were harvested annually the average cost of harvesting was cheaper with the combine, (4) the average total acre cost for combining approximated two-thirds as much, and (5) approximately one-fourth as much labor was necessary when the combine was used.

The difficulty found in harvesting and threshing of weedy or unevenly ripening grain has caused the development of the *windrow* and *pickup* method of harvesting. The grain may be placed in the windrow any time after it is ready to cut with a binder, allowed to dry, and later threshed with a combine having a pickup attachment. Windrowing adds about 60 cents per acre to harvesting costs compared with direct combining.

Mechanical corn pickers are being widely used even on small farms. When the farmer is not justified in purchasing the equipment for his individual use alone, he frequently either hires it or buys and does custom picking.

The advantages of mechanical pickers over hand huskers, aside from cost considerations, have been summarized by Myers[8]: (1) The mechanical picker reduces the labor problem involved in hand husking. (2) Husking may be started earlier and completed in a shorter time. (3) The work is easier and more pleasant. (4) A larger corn acreage can be handled with the available labor. He gives the disadvantages as follows: (1) The investment in equipment is materially increased. (2) Weather conditions, particularly late in the husking season, may make husking unsatisfactory and sometimes impossible. (3) More corn may be left in the field unless great care is taken in operating and adjusting the machine. (4) The value of the stalk field for pasture is reduced.

Myers[8] found that an average of 5.23 hours of man labor was used in husking an acre of corn by hand, 2.72 hours when the one-row picker was used, and 2.21 hours with the two-row picker. The cost of hand husking was $4.46 per acre; husking with the one-row picker, $3.74 per acre; and, with the two-row picker, $3.14. If corn is harvested and shocked and later husked, the costs are substantially greater than those incurred by any of the other methods mentioned.

There is much interest in combining or *field* shelling of corn (Shedd and

Collins[9]), but it has not been practiced as yet very widely. Skelton and Bateman[10] report the harvesting cost per bushel of hand husking was 7 cents; husking with one-row picker, 6 cents; with two-row picker, 5½ cents; and with two-row picker-sheller, 4½ cents.

Corn. A considerable acreage of corn harvested for grain is husked either by hand or with mechanical pickers from the standing stalks. Some, however, is still cut either with machinery or by hand and placed in shocks and husked later.

When corn is cut for the silo, the corn binder is ordinarily used. A machine, however, is sometimes used that harvests the crop and cuts it into silage lengths in the field. When corn is cut and is later to be husked, it is placed in shocks of different sizes. The size of shocks usually varies from 35 to 144 hills per shock. The shocks may be built around a "saddle" made by tying the uncut stalks of 4 hills together. In other cases a wooden horse is used to support the shock until completed. After the shock has been completely built, the horse is removed and used for building the next shock. The shock is drawn tight with a rope and is tied either with twine or with stalks of corn. After the crop has cured, the time required for curing being about 1 month, the ears are usually husked by hand in the field and the stover is shocked in the field. The bundles of stover from four shocks of corn are usually placed together.

The crop after curing in the shock may be husked with the husker and shredder. In this method the labor of hand husking is avoided, and the stover is cut into small pieces. The shredded stover is more easily handled than is the ordinary stover. It is necessary that the stover be dry when shredded to prevent molding in storage. However, the practice of shredding the corn crop has largely gone out of use.

Small Grains. The earliest implement used for harvesting small grains was the sickle, and this was followed in succession by the scythe, the cradle, the self-rake reaper, the self-binding harvester, the header, and the combined harvester-thresher or combine. The rapid development of improved machinery for harvesting small grains has made possible the production of wheat and other small grains on the extensive scale found in the West. On the large wheat farms of the West the header is sometimes used.

The combine and the header have been used on the Pacific Coast for years. In recent years the popularity of the combine has greatly increased, and it is extensively used in the chief wheat-producing areas of the United States. Its use is growing in the East, especially since the windrower has been perfected. The machine commonly used, however, for harvesting small grain is the self-binding harvester. The cradle is seldom used except when it is impracticable to use a better machine.

The self-rake reaper is sometimes used for cutting oats when they are somewhat green, soybeans for seed, buckwheat, etc. However, the use of this machine is now very limited in this country.

When the binder is used in harvesting small grain, laborers follow the reaper and place the bundles of grain in shocks for curing. The shocks usually contain 10 to 16 bundles, two of which are broken and serve as caps to protect the tops of the sheaves from the weather. In the case of oats and barley the shocks are built as for wheat but those of oats are usually somewhat smaller. Rye is shocked like wheat, but sometimes no caps are used. The grain is usually left in the shock until cured, when it is threshed or stored to await threshing. The period required for curing depends largely on the ripeness of the grain when cut and on the weather conditions. However, the crop is usually ready to be removed from the field in about 10 days after cutting.

Buckwheat may be harvested with the self-binding harvester and shocked; each shock may contain 8 to 10 bundles without capping. Much of the crop is grown on mountain land, and the crop is necessarily cut by the cradle, bound into bundles, and shocked.

STORAGE

Shocks, Stacks, Ricks, and Barns. When small grain is harvested with the binder and placed in shocks to cure, the shocks should not be left in the field any longer than necessary for the curing process to be completed. In case of prolonged damp weather the grain is likely to sprout or become lowered in quality because of molding and discoloration. Therefore, as soon as the grain and straw have sufficiently cured for storage in bulk, the crop should be taken from the shock and stored in larger bulk or threshed.

It is usually cheaper to thresh grain crops directly from the fields than to store and then thresh. The procedure to follow will depend upon the transportation facilities and laborers procurable, the weather, and other conditions; more of each being required at one time to thresh directly from the field than to thresh from the bulk in storage. It is to be remembered that the grain may heat in storage if the threshing is done from the field. However, if the grain is spread in a thin layer 1 or 2 feet deep and stirred now and then, the damage is likely to be small. If the crop is kept in bulk for a while before threshing, the heating process takes place without any likelihood of damage. Thus, threshing before the grain goes through the heating process may result in low quality, because of lowered germination and bin burning.

When hauled from the field the small-grain crops are usually stored in stacks, ricks, or barns. The safest and most advisable place of storage is in covered sheds or barns, for here the crop is protected from unfavorable

weather conditions. It is more desirable to store the crop in ricks than in stacks. Stacks are usually built small and round, and a comparatively high percentage of the crop is exposed to the weather. In certain sections of the country it is a common practice to store the unthreshed grain in small stacks; usually it would be a much better plan to store the crop in large ricks.

When the combine is used, the small-grain crop is harvested and threshed at one operation, except when the windrower is used. The windrower is often used when weeds are present or the crop is not quite ready for harvesting with the combine. It is placed in windrows and allowed to dry. The combine with a pickup attachment is then used to thresh the crop.

Bins. The small grains and shelled corn are stored on the farm in bins. The things to be considered in storing are ease of handling, freedom from dampness, and protection against insects and vermin. The bins should be built so as to secure these conditions as far as practicable. It is desirable to have the bins tight, deep in proportion to the other dimensions, and ratproof. A small exposure of surface area of grain lessens the change of weevil and other infestations in storage. It is sometimes necessary to fumigate grains, and in such cases tight receptacles will ensure better results.

There is less loss to grain preserved in bins, which also prevents deterioration in storage. Gross and Walkden[11] report less than 1 per cent deterioration of wheat and shelled corn in storage. It is more important that the grain be dry when stored. The maximum moisture content of grain combined safe for storage is as follows: shelled corn, 13 per cent; hard red spring wheat, 13 per cent; soft red winter wheat, 12.5 per cent; and hard red winter wheat, 12 per cent. Insects attacking stored grain are not active at temperatures below 40°F. and multiply rapidly only at temperatures above 70°F.

Cribs. Ear corn is commonly stored in slatted cribs or granaries. Storage houses of such a nature allow good ventilation and at the same time prevent material damage from weather. This method of storage is far superior to keeping the corn out in the open or in poorly ventilated houses. Ventilation is very important in the North, where corn is sometimes not mature when stored. The percentage of moisture often runs very high, and, if the crop does not dry out quickly, great damage from molding is likely to ensue. Hume and Center,[12] in Illinois, found that ear corn lost in a period of 12 months from 12 to 20 per cent by shrinkage. Welton,[13] in Ohio, found, as an average for 8 years, that well-matured corn placed in a box enclosed on two sides with wire netting lost 20.27 per cent in weight from Nov. 1 to Sept. 1. The loss for the same period of time based on a 5-year average for damp corn, the grain of which con-

tained at the beginning 30.29 per cent moisture and the cobs 50.21 per cent, was 28.65 per cent. The loss was, therefore, 8.38 per cent greater in case of the damp corn.

Shrinkage in Grain. It is important to know the amount of shrinkage likely to take place when grain is stored. This loss as well as that from

TABLE 9. SHRINKAGE IN EAR CORN IN STORAGE

Storage from Nov. 1	Mature, 8-yr. average, per cent	Damp, 5-yr. average, per cent
Dec. 1	5.28	4.75
Jan. 1	7.03	7.90
Feb. 1	8.11	10.30
Mar. 1	9.42	12.45
Apr. 1	11.62	18.20
May 1	16.00	23.55
June 1	19.03	27.45
July 1	20.03	28.85
Aug. 1	20.41	29.20
Sept. 1	20.37	28.65
Oct. 1	19.18	28.15

rats and mice should be taken into consideration when a farmer is deciding whether the crop can be more profitably sold at harvest or at some later date. The loss in shrinkage results from drying and by decrease of dry matter brought about by respiration and loss of certain gases, chiefly carbon dioxide.

Corn. Duvel and Duval[14] found the loss by shrinkage of shelled corn in transit to be greatest in grain having a high percentage of moisture. Corn having 19.8 per cent moisture when loaded had become hot, sour, and discolored and had lost 3.65 per cent by shrinkage in 27 days. Corn having 16.7 per cent moisture when loaded did not show any marked increase in temperature and had lost only 0.18 per cent by shrinkage in the 27 days.

The loss in storage from shrinkage of grain as reported by Welton[13] is shown in Table 9.

The average percentage of moisture at the beginning in the shelled grain of the mature and damp corn was 24.91 per cent and 30.29 per cent, respectively; in the cobs it was 41.51 per cent and 50.21 per cent, respectively. In this experiment, 100 pounds of ear corn was placed in a wooden box, two sides of which were enclosed with wire netting, and placed in the loft of a corn crib.

Small Grains. Welton[13] reports that wheat lost 0.41 per cent while being stored from Aug. 29 to Sept. 2 of the following year. At the same

time, oats gained 0.17 per cent, and rye lost 0.90 per cent. The grains were stored in bins in a granary, 40 bushels of each being used.

Soybeans. According to Welton[13] the percentage of shrinkage of soybean seed, containing 17.67 per cent moisture at time of storage, was 3.76 per cent from Nov. 2 to Oct. 23 of the following year.

SOME INSECT PESTS

Angoumois Moth. In stored grain the Angoumois grain moth or fly weevil (*Sitrotoga cerealella*) is very destructive and is the insect most commonly found in stored grain. The adult is a moth measuring only about ½ inch across the expanded wings, light gray to buff in color, with a black spot about midway of each wing.

The adult deposits its eggs upon exposed grain either in the field or in storage. The eggs hatch in from 4 to 7 days, and the larvae bore into the kernels and feed on the interior for about 3 weeks, when they become full grown. The larvae pupate for from 6 to 10 days and then emerge as adults through cavities previously made by the larvae for this purpose. Several generations are produced each year. The insect overwinters in the larval stage inside grain and in the early spring pupates and emerges as a moth about the time wheat begins to head. The injury to the grain is done by the larva, which consumes the interior.

Control. In control of the insect, prompt harvesting and then storage under conditions unfavorable to the insect attacks are recommended. Kyle[15] has shown that corn with long tight husks is less injured by this insect than ears not well covered. In cases of infestation the insects may be destroyed by the use of 5 pounds of carbon bisulphide to each 100 bushels of grain or 1,000 cubic feet of space. The treatment must be given in tight bins or containers, and, as the fumes are highly inflammable, all fire should be kept away. The liquid may be poured on top of the grain and the grain covered for 24 to 48 hours, when the cover may be removed to allow the grain to air.

Other fumigants mentioned by Cotton[16,17] are (1) ethylene dichloride–carbon tetrachloride mixture, (2) ethylene dichloride–carbon tetrachloride–methyl bromide mixture, and (3) ethylene dibromide and carbon tetrachloride.

DDT has also proved effective and economical in the control of some of the insects attacking grain in storage. It may be applied to walls, ceilings, and floor of the storage space and to the grain itself. *Grain treated with DDT cannot be used for any kind of feed* (Stanley[18]).

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Topics for Discussion

1. If a farmer has one crop ready to harvest and another greatly in need of cultivation, which should be given first attention?

2. Why is wheat harvested with combines in some sections, with binders in others, and with cradles in still others?

3. Why does the western farmer husk corn from standing stalks in the field, whereas the eastern farmer cuts the corn and husks from shocks?

4. Under what conditions is it wise to hold grain on the farm for a prospective rise in price?

5. Does the use of laborsaving machinery reduce the cost of production, and what are the main reasons for its use?

CHAPTER XIV

HAYMAKING

In the production of good hay it is essential that it be harvested at the right stage of development and cured in the proper manner. Failure on the part of the producer to give sufficient attention to these two factors is likely to result in the production of inferior hay.

Losses from Delayed Harvesting. The losses resulting from the delayed harvesting of forage crops are due largely to one or more of

FIG. 19. Mowing hay with tractor, St. George, Utah. (*U.S. Dept. Agr. photograph by Ackerman.*)

the following causes: (1) shattering of the leaves, (2) lodging, (3) reduction in palatability, (4) decrease in nutritive value, and (5) lower yields of subsequent cuttings.

Shattering. The loss from shattering is especially noticeable in the case of leguminous crops. When the harvesting of crops is delayed too long, there is a great tendency for the leaves to dry and fall to the ground or to break off in handling. This loss should be avoided, since the leaves of legumes are usually very high in feeding value as compared with the other vegetative parts of the plant.

Lodging. Plants growing on rich land often have a tendency to lodge, especially in seasons of much rainfall. After the crop has fallen to the

ground it is difficult to cut with the mower, and much is left in the field. In addition to the loss due to failure to secure all the crop, the products obtained are often damaged because of the contact with moist or wet ground. Some of the forage plants have a more marked tendency to lodge than others, and this fact is strikingly true of alsike clover and mammoth clover as compared with red clover.

Reduction in Palatability. As a rule the palatability of forage crops decreases with the increase in development. This is true at least after the plants have passed the best stage of development so far as the production of the maximum amount of digestible nutrients is concerned. With full development is usually found a woody condition of the stems and a relatively high percentage of crude fiber. This is especially true of orchard grass.

Decrease in Nutritive Value. There is generally a decrease in digestibility and feeding of forage crops when the stage of maturity is reached. Waters,[1] in Missouri, found in regard to digestibility of nutrients in timothy that the optimum yields of dry matter, digestible protein, digestible crude fiber, digestible ash, and digestible nitrogen-free extracts were reached when the plants were in full bloom. When the seeds were ripe, as compared with the stage of full bloom, the digestible dry matter was only eight-tenths as much. This stage showed less than two-thirds as much digestible protein, approximately eight-tenths as much digestible nitrogen-free extract, and less than nine-tenths as much digestible fiber.

When forage crops approach maturity a loss in dry matter is often apparent. This loss may result from shattering of leaves and finer parts of the stems; from respiration; from translocation of material to the bulbs in plants like timothy, and to the seeds in plants like wheat, oats, and corn; and from loss by solvent action of rain. The latter loss has been shown to be greater when the crop is mature than when immature.

Lower Yields of Subsequent Cuttings. The effect of the time of cutting forage crops is not only important from the standpoint of the immediate crop, but in the consideration of the subsequent cuttings. In some cases it seems that allowing a crop to become fully developed does not reduce the yield of the subsequent cutting but actually increases it. On the other hand, in some instances when the crop is allowed to mature, the yield of the subsequent cutting is smaller than if the preceding crop had been cut at a stage before maturity.

Losses from Premature Harvesting. Under normal conditions it is poor economy to harvest forage crops too soon. The disadvantages likely to occur are (1) lower yields of food constituents, (2) lower yields of dry matter, and (3) greater difficulty in curing.

Lower Yield of Food Constituents. The results of Trowbridge, Haigh, and Moulton,[2] in Missouri, show that, if timothy hay is cut too soon,

the yields of dry matter and food constituents are lower than those of hay cut in a later stage of development. The percentages of protein, fat, and ash are higher in the earlier stages, but the total production of these constituents is lower owing to a smaller production of dry matter at this time.

Hunt,[3] in Illinois, found that mammoth clover when beginning to bloom as compared with that in full bloom produced less organic matter, crude protein, crude fiber, and nitrogen-free extract, but practically the same amount of crude fat.

As a rule there is a higher percentage of protein, ash, and fat in the early cuttings of forage crops, and the percentage of digestibility is also higher, as compared with cuttings made in later stages. The percentages of crude fiber and nitrogen-free extract are usually higher in the late cuttings. However, it is usually found that forage crops cut early in the stage of development produce a smaller yield per acre of digestible food constituents than those harvested at the proper stage.

Lower Yield of Dry Matter. The yield of dry matter usually increases until full development is reached, and then a decrease occurs. Trowbridge, Haigh, and Moulton[2] found the dry matter of timothy hay to increase from early development until the seeds were in the dough stage. After the dough stage was reached, there was a decrease in the yield of dry matter.

Hunt[3] found that with red clover the digestible dry matter decreased from the time the heads were in bloom until the heads were all dead. There was more digestible dry matter produced by mammoth clover when in the full-bloom stage than either before or afterwards.

Greater Difficulty in Curing. Forage crops cut in the early stage of development contain a higher percentage of water than those cut in the later stages. For this reason a longer time is required for curing. Often in the early part of the season the weather conditions are not so favorable as later, and the ground may contain more moisture. These conditions, when they exist, make hay curing more hazardous. For the reasons just enumerated it is often more convenient to harvest forage crops rather late, although the earlier cuttings may be more palatable and result in more completely digestible hay.

THE PROPER STAGE FOR HARVESTING SOME OF THE PRINCIPAL FORAGE CROPS

Grasses. *Timothy* is the main grass plant cut for hay in the United States. According to Waters[1] the crop should be harvested when in the stage of full bloom as at this time the highest yield of digestible nutrients is produced. The highest yield of hay was secured when the plants had formed seed.

Brome grass should be cut when in full bloom, as at this time the highest yield of digestible nutrients is produced.

Orchard grass should usually be cut when in full bloom. If left longer than this stage, the stems become woody, and the crop becomes low in digestibility. If the crop is cut at the proper stage and if the weather and soil conditions are favorable, a good second crop will be secured. The second crop is seldom as large as the first.

Redtop is seldom seeded alone but is commonly included in mixtures, especially with timothy. The time of maturity of the associated plants will largely govern the time the redtop will be cut. As a rule the associated plants are more important than the redtop. However, redtop, when seeded alone, should be cut when in full bloom.

Bermuda grass and Johnson grass furnish much of the hay produced by permanent grasses in the Southern states. Several cuttings each year can be obtained from these grasses. They should be cut when in full bloom, as at this time a larger amount of digestible nutrients per acre will be secured, and the succeeding crops will be larger than when cut at a later stage of development.

Millet should be cut for hay when just past the bloom stage. This is especially true if the crop is to be fed to horses. Millet is dangerous when fed in too large quantities to horses, but cutting in the early stages lessens the danger and makes the crop more palatable. If the crop is to be fed to cattle or sheep, it may be left until the late milk stage is reached and fed without danger. However, when the crop is cut in the later stages the digestibility is lowered somewhat, but the yield of hay is larger.

Cereals. *Wheat, oats, barley,* and *rye* are commonly harvested for hay in some sections of the United States. Hendry,[4] in California, states that in general cereal hay intended for dairy cattle should be cut when the crop is in the milk stage; when intended for horses, in the dough stage.

Legumes. *Alfalfa* is the most important hay crop grown in this country. Stewart,[5] based on an exhaustive study of the experimental results, states that alfalfa should be cut for hay in the Rocky Mountain region just as soon as the blossoms begin to appear; in the Great Plains, the Gulf Coast, and the central Mississippi Valley, at from half to full bloom; in Wisconsin, in full bloom; and eastward from Minnesota, half bloom or slightly later for common alfalfa and early bloom for the hardy type of alfalfa, such as Grimm. See Fig. 18 on page 125 which shows the acreage of alfalfa in the United States in 1939.

The retention of leaves and a green color are the two things most desired by hay producers, according to Grandfield and Throckmorton.[6] They report that there is a direct correlation between the percentage

of leaves and the percentage of protein. The highest percentage of leaves was obtained when alfalfa was cut in the early bloom stage. The highest yield of hay, as well as the highest yield of protein per acre, was obtained when the hay was cut between the one-tenth and full-bloom stages.

Sweet clover, when harvested for hay in the fall, should be cut late but not so late as to prevent some top growth forming before killing frost occurs. Willard,[7] in Ohio, found that the yield of the next year's crop was much reduced when the fall crop was harvested. The summer hay crop should be cut while the plants are in the bud stage and before the first blooms appear. If harvested later than this stage, there is likely to be a large amount of woody material, and the yield of the subsequent cutting will be reduced.

When in full bloom *red clover* seems to be at the proper stage for cutting. At this stage the largest yields of both hay and digestible nutrients are secured.

Since the main stems continue to grow with the production of new parts, *alsike clover* remains in the proper stage for cutting over a longer period than red clover. The crop should usually be cut when in full bloom. As with red clover, under favorable conditions a second crop is obtained. The yield of the second crop is reduced if the harvest of the first is delayed too long.

Common and *Korean lespedeza* should be cut when the plants are in full bloom.

Cowpeas should not be cut for hay until the first pods are ripe. The plants have an indeterminate habit of growth, and for this reason the harvesting period may extend over a long period of time. If the crop is cut too green, it is difficult to cure, whereas delaying the harvest too long will result in loss of some of the early-maturing leaves.

Harvesting can be delayed, however, without serious loss until many of the pods are ripe.

Soybeans may be cut for hay over a period of several weeks with good results. Other things being equal, soybeans are best harvested when the seeds are well formed and before the lower leaves turn yellow.

Essential Facts about Curing Hay. In the curing process certain changes take place that materially affect the market and feeding quality of the hay. These changes are necessary in order to secure properly cured hay. However, it is essential that the grower handle the crop in a judicious manner in order that the changes which take place may make possible the production of hay of the highest quality.

In the curing process, (1) a change in plant material and (2) a loss of substance take place. Both of these changes affect the market and feeding qualities of hay.

CHANGES IN PLANT MATERIAL DURING THE CURING PROCESS

These changes fall under three heads: (1) reduction of water, (2) enzymatic action, and (3) bleaching.

Reduction of Water. The amount of water in the plants decreases from about 70 per cent in the freshly cut material to about 15 per cent in the air-dried or field-cured hay. Vinall and McKee[8] give some interesting data in regard to moisture contents of various green and field-cured crops. These data are presented in Table 10.

TABLE 10. PERCENTAGE OF MOISTURE IN GREEN AND FIELD-CURED FORAGE

Crop	Green material, per cent				Field-cured hay or fodder, per cent			
	Number of analyses	Average	Maximum	Minimum	Number of analyses	Average	Maximum	Minimum
Alfalfa	23	71.75	82.03	49.30	21	8.44	16.00	4.60
Red clover	43	70.79	91.78	47.13	38	15.26	31.27	6.02
Timothy	56	61.58	78.80	46.98	68	13.18	28.88	6.12
Kentucky bluegrass	18	65.07	82.53	51.67	14	21.16	32.82	14.30
Corn	16	79.33	93.60	51.50	35	42.18	60.17	22.93
Sorghum	11	79.40	86.38	63.88				

The same investigators have compiled data from various sources showing the moisture content of timothy, alfalfa, and red clover at various stages of growth. The average percentage of moisture in the green substance of timothy ranged from 74.4 per cent when the heads were not yet visible to 49.15 per cent when the seed was becoming hard. In the case of alfalfa the range was 83.32 per cent when the crop was 18 inches in height to 55.92 per cent when it was ripe. The variation in the red clover crop was from 82.55 per cent when the heads were not yet visible to 61.05 per cent when the seed was nearly ripe.

Amount of Moisture in Hay when Stored. Vinall and McKee[8] compiled data from different sources and found the percentage of water in hay when placed in storage to be 22.63 per cent. The range was from 6.20 to 36.16 per cent. McClure[9] states that the percentage of water in field-cured hay varies from 15 to 31.3 per cent.

The loss of water in curing hay is variable. When field cured and ready for storage, hay has usually lost about 50 to 60 per cent in weight. This loss includes both reduction in water and reduction in dry matter, the former being much the greater. The loss in water is desirable, since hay with too much water deteriorates when stored. In addition, hay

containing excessive moisture requires more labor in handling than properly cured hay.

Rate of Loss of Moisture. The rate of loss of moisture seems to depend on the crop and on weather conditions, as shown by Vinall and McKee.[10] At Chico, California, the loss of moisture from alfalfa was much more rapid than at Arlington, Virginia. At Chico the temperature is higher and the humidity lower. The results in Table 11 are reported by these investigators.

TABLE 11. RATE OF LOSS OF MOISTURE FROM VARIOUS HAY PLANTS AFTER CUTTING

Crop and location	Moisture loss, per cent				
	½ hr.	1 hr.	2 hr.	3 hr.	4 hr.
Alfalfa at Chico, Cal.	..	17	35	..	69
Alfalfa at Arlington Farm, Va.	6	14	23	28	32
Tall oat grass and orchard grass at Arlington Farm, Va.	5	12	24	30	34
Timothy at New London, Ohio	6	10	18	25	30
Sorghum at Hays, Kans.	2	5	9	12	13

Loss of Weight in Storage. After hay is stored, a certain amount of shrinkage takes place. The shrinkage resulting is due to loss of moisture and dry matter. In the case of well-cured hay the chief loss in storage is caused by reduction in water content. On the other hand, when hay is stored undercured or wet, a large loss results from fermentation. If the crop when stored contains about the same amount of moisture as the atmosphere, there is little change in weight. Forage extremely dry when stored may gain weight. Hay decreases in weight when first stored and recovers some of the loss later. When the atmosphere contains more moisture than the forage, the latter absorbs moisture from the former, and vice versa. In case of well-cured hay, it may be seen that the moisture content of the hay when stored and the changes in the humidity of the atmosphere largely govern the amount of shrinkage of hay. The data showing the shrinkage of hay as reported by McClure[9] from a compilation of results from various sources are shown in Table 12.

McClure[9] gives a rather complete résumé of data on shrinkage. The extreme loss of hay due to shrinkage in storage amounted to 44.2 per cent. The minimum loss was only 0.29 per cent. There were actual gains in some experiments varying from 0.4 to 10.7 per cent. The extremes show a range of gain and loss amounting to 55 per cent from time

TABLE 12. WATER CONTENT OF FIELD-CURED AND WELL-CURED BARN AND STACK-CURED HAY

	Field-cured hay, maximum per cent	Well-cured barn or stack hay, per cent		
		Minimum	Average	Difference between minimum and maximum water content
Timothy (all analyses)	28.9	6.1	11.6	22.8
Timothy, early to full bloom	28.9	7.0	12.8	21.9
Timothy, late bloom to early seed	21.6	7.0	14.1	14.6
Redtop (all analyses)	28.0	6.8	9.8	22.2
Redtop, in bloom	....	6.8	8.0	
Alsike clover	....	5.3	12.3	
Alfalfa (all analyses)	30.0	4.6	8.6	25.4
Red clover (all analyses)	31.3	6.0	13.0	25.3
Cowpea	....	7.6	9.7	
Soybeans	20.0	6.1	8.6	13.9
Johnson grass	....	...	10.1	
Barley	15.0	6.4	10.0	8.6
Oat	26.5	9.5	12.0	17.0
Rye	....	...	8.1	
Wheat	....	...	8.1	
Prairie	17.1	6.5	10.0	10.6

hay is stored until well cured in the barn or stack. It is difficult to state the average amount of shrinkage that will take place when hay is stored. The difficulty is due to the fact that shrinkage depends upon several factors, such as the variation in the time of cutting, method of curing, and weather conditions. These factors and causes will bring about great variations.

Enzymatic Changes in Composition during Curing. During the curing process certain changes take place in the composition of the plant as a result of fermentation brought about by enzymes. Curing is not simply a drying process. A certain amount of fermentation is desirable in curing hay. Proper fermentation apparently increases the digestibility of the forage and gives it a pleasant aroma and a good flavor. On the other hand, excessive fermentation will lower the quality of the hay. It seems that a high moisture content is necessary for excessive fermentation and that hay properly cured is not likely to be injured by the process. Hay that has been wetted by rain or insufficiently cured, when stored in such condition, often ferments and heats. As a result the quality

of the hay is lowered. According to Keable and Wale at Wye, England (McClure[9]), there is a direct relation between temperature and moisture content of hay. With sufficient moisture the temperature may become very high. However, according to these investigators the dry matter is not likely to be damaged until the temperature exceeds 150°F. Hoffman in Germany (McClure[9]) found that the organic matter of hay is destroyed at a temperature of 226°F. or over. He states:

> The fermentation of the hay causes the temperature of 133°F. At this temperature a more violent oxidation takes place, and the temperature rises to about 194°F. Other processes then take place which char the material and cause a slow rise in temperature to 226°F. When this temperature is reached, the hay rapidly heats, and the charring proceeds rapidly. All these processes destroy at least half of the material. Theoretically the temperature may reach 374°F.
>
> According to the tests made, clover hay may become ignited at 302 to 392°F. Therefore the temperature may rise sufficiently high to cause spontaneous combustion. Oxygen from the air is essential to combustion.

Bleaching. Bleaching is caused by the destruction of the chlorophyll by sunlight. When hay is bleached, it becomes brittle; the quality is reduced because of reduced palatability and digestibility, poor color, loss of aroma, and loss in weight. The bleaching action seems to be increased by rain and dew. The loss of green color means a loss of vitamin A, which is so important in livestock feeding.

Loss of Substances during Curing. In addition to the loss of water in curing of hay there is often a loss in dry matter. The latter loss is due to some process of oxidation as well as to loss of leaves and finer portions of the stems. The investigations of Shuey[11] show that the loss of dry matter in field-cured alfalfa was 12.0 per cent, whereas field-cured alfalfa exposed to rain lost 22.8 per cent. The loss of leaves under favorable conditions of field curing was 5.6 per cent and when exposed to rain, 17.6 per cent. The results presented in Table 13 are taken from Shuey.[11]

TABLE 13. EFFECT OF FIELD CURING AND RAIN ON CHANGES IN CHEMICAL ANALYSIS OF ALFALFA HAY IN KANSAS (LOSS PER CENT)

Treatment	Protein, per cent	Sugar, per cent	Starch, per cent	Fiber, per cent
Laboratory cured (no loss)	17.83	4.18	10.71	27.50
Field cured (12 per cent loss)	13.77	2.25	12.40	30.51
Exposed to rains and field cured (22.8 per cent loss)	11.33	0.75	14.12	36.49

The loss of protein due to field curing and field curing exposed to rain was 32 and 51 per cent, respectively; the loss in sugar content was 53 and 86 per cent, respectively. There was a relative increase in starch and fiber.

Willard[12] states that the loss by weathering during field curing in Kansas is due to fermentation processes, mechanical losses, and the dissolving out and removal of substances. It was found that alfalfa exposed to three showers totaling 1.76 inches lost 60 per cent of its protein, one-third of its fats, 41 per cent of its nitrogen-free extract, and 28.7 per cent of its ash. The percentage of fiber relatively increased.

The results of experiments indicate that a portion of the dry matter of the growing plants is lost by washing by rains. The loss seems to increase as the plants approach maturity. Trowbridge, Haigh, and Moulton[2] found the dry matter of timothy to decrease 394 pounds per acre from the time the seeds were all in the dough stage until the seeds were ripe. The loss is attributed to falling off of leaves and washing by rains. LeClerc and Breazeale[13] state that plants exude salts upon their surface and that these salts are washed back to the soil by rain.

Woodward and others[14] state that when crops are harvested there is an inevitable loss of nutrients and that the loss of carotene starts at once.

Loss of Substance after Storing. Cooke,[15] at the Colorado Experiment Station, found that alfalfa stacked for 8 months in the open lost 10 per cent of dry matter and only 2.5 per cent when stored in a barn for the same period. There was no damaged hay in the barn, but there was some in the stack. Calculated on the basis of hay suitable for feed at the end of the 8 months, the loss in the stack was 12.4 per cent whereas that in the barn was 2.5 per cent. The hay in the stack lost 2 per cent of ether extract, 10.5 per cent of crude protein, 4.4 per cent of crude fiber, and 16.8 per cent of nitrogen-free extract.

Sanborn,[16] at the Utah Experiment Station, reports that clover hay stacked in the open, stored in the barn, or suspended, lost no dry matter during a period of 9 months. Timothy stored for 9 months in the barn lost 10 per cent of its dry matter while that stacked in the open lost but little. Sanborn[17] reports a loss of 14.9 per cent of dry matter when a ton of timothy hay was stored for 10½ months in the center of a mow. Another lot of timothy hay placed in a bag and suspended in the barn for 7 months lost no dry matter.

Field-cured hays practically always contain enough moisture to cause them to go through a sweat when stored. It results not only in the loss of carotene but of other valuable feed constituents as well (Woodward and others[14]).

Relation of Changes during Curing to Market Quality. The better grades of hay should be properly cured by the time they are ready to be sold. The highest prices are paid for hay with good or natural green color. The quality of hay is markedly affected by the methods used in curing and storage, and by weather conditions. When proper methods are used and the weather conditions are favorable, prime or high-quality hay usually results. Such hay is bright; is as green as possible; has a

FIG. 20. A pickup hay baler in operation.

good aroma; retains its leaves, especially the legumes; and is free from dust or mold. Hay of this grade is comparatively high in palatability, digestibility, and feeding value.

In order to obtain high quality it is necessary for the crop to have lost sufficient water to prevent excessive heating when stored or baled. Hay baled when too green brings a low price on the market, and there is little demand for it. There seems to be a direct relation between the amount of moisture present in hay and the degree of fermentation and heating. A certain amount of fermentation is desirable, as the process seems to make the hay more palatable and digestible and gives it a characteristic aroma. However, excessive fermentation is undesirable and results in a reduction of dry matter, palatability, and digestibility. The hay, moreover, is off color and moldy. Hay containing the proper amount of moisture when stored usually undergoes about the optimum amount of fermentation.

Stained and bleached hay is discriminated against on the market.

Such hay is off color and is reduced in feeding value, palatability, and digestibility. For proper curing, hay should be so handled as not to be exposed any more than necessary to rain or sunlight. The lack of the desirable green color is especially noticeable in hays that have been exposed to rain and to the sun for too long a period.

The storage of hay is important from the market standpoint. It should be stored so as to prevent damage in so far as possible. There

FIG. 21. A pickup hay and straw chopper in operation on a Delaware County farm in Ohio. The chopped material is being loaded into a specially constructed wire-topped wagon. (*Reprinted by special permission of Country Gentleman, copyright*, 1947, *by the Curtis Publishing Company.*)

seems to be but little loss of dry matter in hay due to storage, provided the crop is properly cured when placed in storage. However, the bulk should be protected from the weather to prevent damage by rain and snow. Hay stacked in the open is usually damaged on the outside, and this portion makes a low-grade product. This same fact holds true in the case of baled hay when stored and not properly protected from unfavorable weather conditions. The outside of the bale becomes discolored, and the entire bale sells on the basis of the market value of the hay on the exterior. If a hay of high quality is to be placed on the market it is obvious that proper handling is absolutely essential.

Practices in Curing Some of the Principal Crops. During dry weather haymaking is a simple process, but in wet weather the process is more complicated. Under humid conditions two processes are used to hasten the curing. The first is to accomplish more rapid drying of the hay by keeping it well aired, which may be accomplished by turning with a

pitchfork or tedder. The second is to place the hay in cocks from the windrow to reduce the surface exposed to rain or dew.

In the humid sections of the country, hay is sometimes allowed to finish field curing in cocks. This practice usually produces a higher quality hay than windrow curing, but it is more expensive and laborious and is being followed less and less. Where a large acreage of hay is harvested under dry conditions, it is a common practice to cure hay from the windrow rather than from the cock. At the present time the greater part of the hay crop is made by allowing the forage to wilt in the swath and then raking into windrows where the field curing is completed. At times, especially in the western and central part of the United States, the hay crop is completely cured in the swath and lifted from the swath by the loader and either stored or baled.

Kiesselbach and Anderson,[18] in Nebraska, state, "Judicious partial swath curing to hasten the rate of drying, followed by windrowing and by prompt storage when cured, would seem to be the best practice for this region." This practice is generally sound for any region.

The high price and scarcity of labor have brought substantial changes in the methods of curing hay. The use of hand labor is held to a minimum, and an increasingly high percentage of hay is baled in the field, usually from the windrow.

Another practice followed to reduce labor and save storage space is to chop the hay and blow it into the barn. From 2 to 2½ times as much chopped hay can be stored in a given space as can unchopped hay.

Artificial Drying of Hay. The artificial drying of hay is growing in popularity because of its higher feeding value, compared to field-cured hay. In Tennessee,[19] barn-cured hay graded 54 per cent U.S. No. 1; 34 per cent U.S. No. 2; 7 per cent U.S. No. 3; and 5 per cent U.S. Sample grade. Field-cured hay graded 9 per cent U.S. No. 1; 26 per cent U.S. No. 2; 35 per cent U.S. No. 3; and 30 per cent U.S. Sample grade. The main advantages of artificial drying are that more leaves, protein, and carotene (Vitamin A) are saved than is possible in field curing.

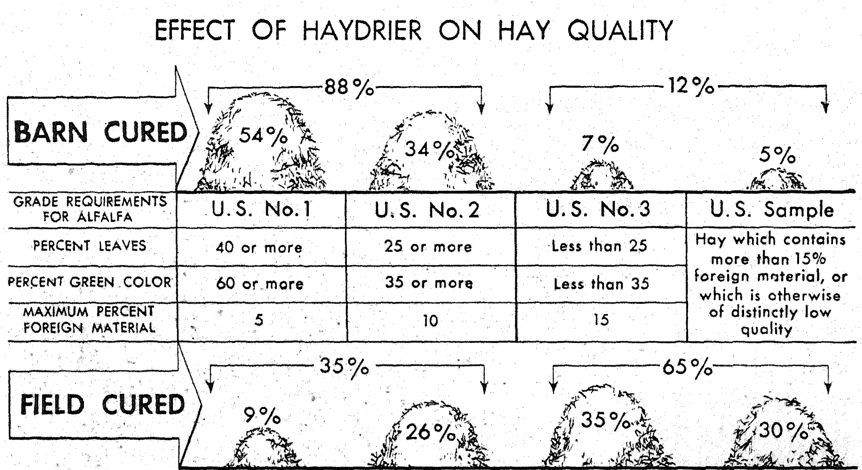
The newer methods of curing hay have many advantages over field curing. According to LeClerc,[20] "even with normal practices under normal weather conditions, haymaking in many sections of the country is accompanied by a loss of dry matter amounting to 10 per cent or more." The annual loss to farmers, therefore, amounts to at least 75 million dollars.

Advantages in Using Barn Hay Drier. This method of curing hay

1. Eliminates the danger of loss due to unfavorable weather.
2. Saves 30 to 50 per cent more leaves.
3. Retains 40 to 50 per cent more green color.

4. Retains 15 to 25 per cent more protein.
5. Increases hay-storage capacity up to 50 per cent.
6. Reduces fire hazard due to spontaneous combustion.
7. Allows hay to be cut and stored in barn the same day.

Legumes. Since they are more succulent and since the leaves shatter more easily, most legumes are more difficult to cure for hay than the grasses. When alfalfa and the clovers are cured, the hay is allowed to wilt somewhat in the swath and then is stirred, if the crop is heavy, by



GRADE REQUIREMENTS FOR ALFALFA	U.S. No. 1	U.S. No. 2	U.S. No. 3	U.S. Sample
PERCENT LEAVES	40 or more	25 or more	Less than 25	Hay which contains more than 15% foreign material, or which is otherwise of distinctly low quality
PERCENT GREEN COLOR	60 or more	35 or more	Less than 35	
MAXIMUM PERCENT FOREIGN MATERIAL	5	10	15	

Average of 91 samples collected in 1942, 1943 and 1944 from farms in Tennessee and Virginia.
Grading done by United States Department of Agriculture

FIG. 22. Comparison of barn-cured and field-cured hay in reference to grades of hay produced. (*Tenn. Agr. Col. Ext. Service Leaflet No.* 91.)

use of the tedder. After a few hours, before the leaves have begun to get dry and brittle, the hay is raked into windrows and is allowed to remain in this condition until dry enough for storage. If the hay is to be put into cocks, it should be placed there soon after raking.

In the curing of legumes the loss of leaves should be prevented in so far as practicable, for the leaves are the most valuable part of the plants.

Soybean hay can be more easily cured than can cowpea hay. However, with these two legumes, as with alfalfa and the clovers, the object is to prevent the loss of the leaves in so far as is practicable. In the curing of either cowpeas or soybeans the crop is allowed to wilt in the swath and is put into windrows, where it is left for 2 or 3 days. The hay is then placed in small cocks or around perches or pyramids and left until ready for storage.

Grasses. The grass crop can be cured into hay much more easily than can legumes. The period required for curing is shorter, and the loss from shattering of leaves is less. In favorable haymaking weather,

especially when the crop is fully developed, the crop may be cut in the morning and stored in the afternoon, but usually the crop is cut one day and stored the next. The general practice followed in the curing of grass crops for hay, if the crop is heavy, is to allow the hay to wilt in the swath and then to ted it. A few hours after tedding the hay is raked into windrows, cured, and stored. In case the highest grade of hay is desired or the weather conditions are unfavorable, the hay should be placed in cocks as soon as raked and allowed to cure there. When the crop is allowed to

FIG. 23. Hay baled with a pickup hay baler in Washoe County, Nevada. (*U.S. Dept. Agr. photograph by Ackerman.*)

cure in the windrow rather than in the cock, much larger areas can be handled, and the hay can be produced more economically. There is, however, some sacrifice in quality by windrow curing.

Summary of General Rules for Curing Hay. In the curing of hay there is a loss of water; a change in the chemical condition, due to the fermentation, with the development of a characteristic aroma; and bleaching, due to the destruction of chlorophyll. The first two processes are desirable whereas the last is not. In curing hay, one should not expose it to the sun any longer than necessary. Hay properly cured with a short period of exposure to the sun loses its water comparatively slowly, the fermentation is not excessive, and the hay retains the aroma and a desirable green color. Moreover, hay thus cured is palatable and digestible and of high quality generally.

Hay is usually wilted in the swath, raked into windrows, allowed to cure there, and then stored. If the crop is heavy, it is stirred by tedding before raking into windrows.

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Topics for Discussion

1. What is the relative value of clover and timothy cut at the following stages: (1) just before bloom, (2) in full bloom, (3) when seeds are mature?

2. Which will likely persist the longer and produce the larger yield, a hay crop cut twice in a season or one cut four times?

3. What are the advantages or disadvantages in producing the farm hay crop from perennial or biennial forage plants rather than from annuals?

4. Is hay made in bright sunlight better or poorer than that made in the shade?

CHAPTER XV

SILAGE

The practice of ensiling crops was probably not followed by the Romans. It was used by the Germans at an early date, and the first recorded attempt to ensile green maize was made in 1861 by Adolph Reihler. In this country the first silo was built by Manly Miles in 1875. In 1876, Francis Morris of Oakland Manor, near Ellicott City, Maryland, built a silo and filled it with corn. In both of these instances the silo was built in the ground. The work of F. H. King was started in 1891 and has done much to make the silo and the practice of ensiling crops a success. Rapid progress has been made in building silos and in making silage from green crops. At the present time an enormous acreage of crops is ensiled and fed to livestock each year.

Economy of Silage. Silage is used throughout the United States but especially in the dairy sections of the country. However, it serves as an excellent food for beef cattle and sheep, as well as for dairy stock. According to Woodward[1] and others the reasons for the popularity of silage are

(1) More feed can be stored in a given space in the form of silage than in the form of fodder or hay. (2) There is a smaller loss of food material when a crop is made into silage than when cured as fodder or hay. (3) Corn silage is a more efficient food than corn fodder. (4) An acre of corn can be placed in the silo at less cost than the same acre can be husked and shredded. (5) Crops can be put in the silo during weather that could not be utilized in making hay or curing fodder. (6) More stock can be kept on a given area of land when silage is the basis of the ration. (7) There is less waste in feeding silage than in feeding fodder. Good silage properly fed is all consumed. (8) Silage is very palatable. (9) Silage, like other succulent feeds, has a beneficial effect upon the digestive organs. (10) Silage is the cheapest and best form in which a succulent feed can be provided for winter use. (11) Silage can be used for supplementing pastures more economically than can soiling crops, because it requires less labor, and silage is more palatable. (12) Converting the corn crop into silage clears the land and leaves it ready for another crop.

Crops for Silage. A crop suitable for making silage should give a high yield of material that, when placed in the silo, will produce a nutritious, palatable, and easily digestible feed. The principal silage crop of the United States is corn. It probably constitutes more than 90 per

cent of the total amount. In the central southern Great Plains, sorghum is the chief silage crop. The droughty conditions of these regions are better suited to sorghum production than to the production of corn. In the Southern states, corn, sorghum, Japanese cane, pearl millet, and other crops are used for silage purposes. Sunflowers are adapted to the Northern sections of the country and the higher altitudes of the Western states. Sunflowers are much more resistant to frost than corn.

The use of grasses, legumes, and small-grain crops for making silage is becoming increasingly popular. Any of these crops that can be utilized as hay or roughage can be made into silage. Those crops listed by Ragsdale and Herman[2] are

Legumes	Grasses	Cereals
Alfalfa	Bluegrass	Barley
Alsike clover	Johnson grass	Oats
Cowpeas	Millet	Rye
Crimson clover	Mixed pasture	Wheat
Lespedeza	Orchard grass	
Peas—all varieties	Prairie grass	
Red clover	Redtop	
Soybeans	Sudan grass	
Sweet clover	Timothy	
Vetch		

Some of the advantages listed by Ragsdale and Herman[2] for making silage from grasses, legumes, and small-grain crops, compared to harvesting these crops for hay or roughage are

1. Silage may be made during periods unfavorable for the field curing of hay.
2. A greater proportion of feed nutrients are saved, as losses due to rains, bleaching, and shattering of leaves are reduced.
3. Early season crops may be used to supplement short pastures.
4. Weed seeds are prevented from being spread, as most weed seeds are destroyed by the fermentation processes that occur in the silo.
5. Carotene content is better preserved.
6. Less storage space is required.
7. Fits into soil-conservation program better, as the necessity for growing soil-depleting crops is lessened.
8. Good "drought insurance" agent in shortage of green pastures.

Rate of Planting Silage Crops. Intertilled crops, such as corn, sunflowers, and sorghums, to be used for silage should be planted at a somewhat thicker rate than those grown for grain purposes. However, the rate of planting should not be so heavy as to interfere too greatly with grain production. The rate of planting will, of course, vary with the crop, climate, and productivity of the soil.

The rate of planting legumes, grasses, and small-grain crops to be used for silage is the same as that for hay or roughage.

Stage of Cutting. Crops for silage should be cut when the largest amount of digestible nutrients per acre will be secured, rather than the greatest amount of green material. Crops cut when too green are likely to produce a lower amount of food constituents per acre and to give a low-grade watery silage.

Corn. In order to secure the greatest yield per acre of valuable nutrients, corn should be cut for silage when the kernels are fully glazed and when the early ears are well ripened.

Sunflowers. Sunflowers should be harvested for silage when the seeds are in the dough stage. At this stage the flower rays are dry and partly fallen.

Vinall[3] advises cutting sunflowers for ensilage before the seeds have reached the hard dough stage. In dry climates the plants should be harvested at an earlier stage of development than in humid regions. Most writers advise cutting sunflowers for silage when only 50 to 60 per cent of the stalks are in bloom. It is inadvisable to cut the crop when too green, as the silage made is likely to be watery and the shrinkage percentage high.

Sorghum. Scott[4] states that grain sorghums should be cut for silage when the seeds are in the stiff dough stage.

Legumes, Grasses, and Small-grain Crops. Ragsdale and Herman[2] recommend that legumes and grasses be harvested for silage at the same stage of growth as that in which they would be cut for the best quality of hay. They recommend that small grains be cut for silage as soon as they are headed out, or in the milk stage.

Changes in Silage. When green crops are placed in the silo the first noticeable change to take place is in the composition of gases, according to Peterson, Hastings, and Fred.[5] The oxygen disappears in from 4 to 5 hours, and carbon dioxide increases for about 48 hours, when it comprises from 60 to 70 per cent of the gases in the silo. It then begins to decrease and continues to do so for several months. The next immediate effect is an increase in temperature, which at the end of 2 weeks is 77°F. near the bottom and 102°F., 4 feet from the top. It continues to rise for the first 2 weeks and then begins to decline, but remains at a high level for from 60 to 70 days.

In from 24 to 48 hours after ensiling, the production of ethyl alcohol and acetic and lactic acids begins. They are formed mainly from the sugars, through fermentation, but also from the pentosans and starches. It is the formation of these products that brings about the change in color of the silage and gives to it the aromatic odor and sour taste. In

from 12 to 24 hours after the green material is placed in the silo, there is a great increase in the number of bacteria, chiefly those producing lactic acid. As the products of fermentation accumulate the bacteria disappear. The silage will now keep indefinitely unless air is allowed to enter. The presence of air or oxygen permits the development of molds.

The composition of corn undergoes a change when made into silage. Perkins[6] found that, when a sack of ground corn was buried in silage and

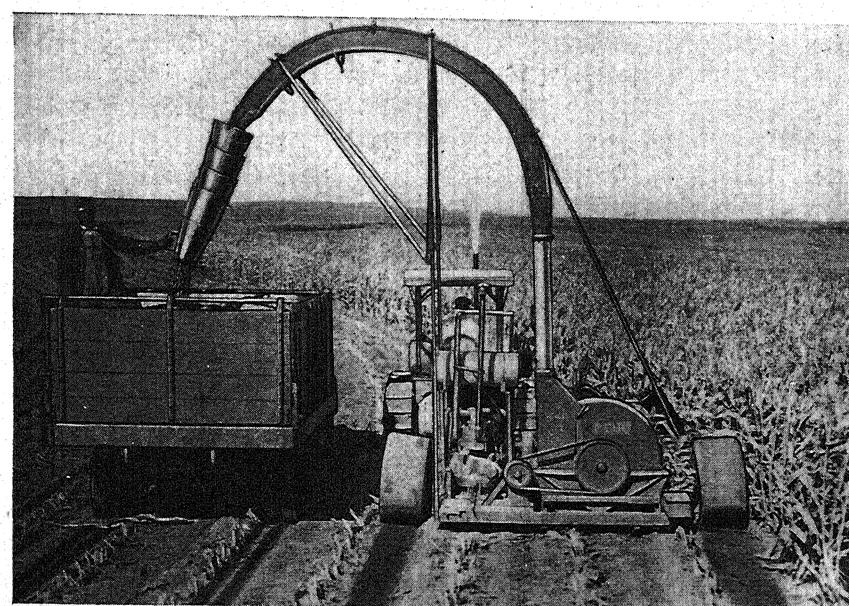

FIG. 24. Silage cutter in operation in the field where silage is being cut and loaded for transporting to the silo, where it is blown into silo. (*Kansas Agr. Expt. Sta.*)

its composition later compared with corn meal that had not been ensiled, the percentage of protein and ash decreased, and the ether extract, crude fiber, and nitrogen-free extract increased.

Good Practices in Making and Preserving Silage. In the production of silage crops a study should be made of the crop or crops best adapted to the conditions under which the silage is to be made.

There is a gain in food constituents in most crops nearly up to maturity. Sometimes, however, there is a loss in the case of crops harvested too late, and it is, therefore, important to know the best stage for cutting the crops and the best stage for storage in the silo. The results of experiments indicate that corn for silage should be cut when the crop is in the hard dough stage.

The harvesting of various crops should be done in the most inexpensive and practical manner. As a general rule, crops for silage can be more

profitably harvested by the use of machines especially made for the purpose. In harvesting such crops as corn, sunflowers, and soybeans for silage they may be cut by hand, with a sled or platform cutter, corn binder, or a combination harvester and silage cutter. The latter machine not only harvests the crop but cuts it into lengths ready to be placed in the silo and elevates the cut material into a wagon drawn alongside.

It was formerly thought that when crops were placed in the silo they should be thoroughly packed to exclude air and prevent spoiling from taking place. During the last few years, it has been found that it is not necessary to pack them unless they are very dry or until the silo is almost filled.

Such crops as corn, sorghum, and sunflowers are easy to preserve as silage, since they are high in carbohydrates, which ferment quickly and develop into lactic acid.

Legumes and grasses are lower in carbohydrates than corn, sorghum, or sunflowers, and the addition of readily fermentable material is advisable when they are placed in the silo or allowed to wilt. Legumes and grasses may be mixed with corn when placed in the silo, and the corn will supply the needed carbohydrates. It is not always practical, however, to mix legumes and grasses with corn, sorghum, or sunflowers. Therefore, molasses is often used to supply the needed carbohydrates.

Molasses contains 50 per cent sugar. In making *molasses silage*, the silage is prepared in the usual way, except that the molasses is added. The molasses may or may not be diluted with water and added to the green material as it enters the cutter, or it may be placed in the blower.

Ragsdale and Herman[2] suggest the addition of from 40 to 80 pounds of blackstrap or cane molasses per ton of silage. The approximate amounts they recommend are

1. Legumes—70 to 80 pounds (6 to 7 gallons).
2. Mixed grasses and legumes—60 to 70 pounds (5 to 6 gallons).
3. Small grains—40 to 50 pounds (3½ to 4 gallons).

The molasses increases the food nutrients, improves the odor and palatability of the silage, and better preserves the carotene, protein, and other nutrients, and the milk produced from it contains about as much vitamin A and carotene as milk produced on silage preserved by any other method, "even though the analyses of the silages themselves may show that they contain only about two-thirds as much of these factors," according to Ragsdale and Herman.[2]

Commercial phosphoric acid (about 68 to 75 per cent) may be used to preserve silage. The acid is diluted at the rate of 1 part of acid by volume to 5 parts of water. *Never add water to the acid.*

The amounts of acid recommended per ton of silage are

1. Legumes—16 pounds ($1\frac{1}{4}$ gallons).
2. Small grains and grasses—8 to 9 pounds ($2\frac{2}{5}$ quarts).

The advantages claimed for *phosphoric acid silage* are that there is little loss of green color or nutrients, the available phosphorus in the ration is increased, and the manure produced by the animals eating the silage is higher in phosphorus.

Another method of making *acidified silage* is known as the A.I.V. method. The purpose of the acid is to prevent undesirable fermentation. The acids used are sulfuric and hydrochloric or a combination of the two. Woodward and others[7] state that the addition of acids does prevent protein breakdown and the development of offensive odors and lessens the losses of dry matter. However, the acid is destructive to masonry, is troublesome to apply, must be neutralized when the silage is fed, adds no nutritive value, and seriously impairs the nutritive value of the silage.

Woodward and Shepherd[8] state, "to offset their disadvantages, the silage possesses a clean acid taste, and the carotene, as commonly determined at present, is more effectively preserved."

The easiest and most practical method of making silage from legumes, grasses, and small-grain crops is to use the *wilting method*, which requires no preservative. In using this method the crop is allowed to dry until the moisture content is between 50 and 70 per cent, preferably around 65 per cent. When crops are harvested for hay they usually contain about 75 per cent moisture. The drier the crop becomes, the greater is the attention that must be given to packing it firm in the silo. Also, the drier the crop becomes, the greater is the loss of carotene (Woodward and others[7] and Woodward[9]).

Loss in the Silo. LeClerc[10] reports results that show that the loss in dry matter of silage was 8.4 per cent in a concrete trench silo and from 16 to 23 per cent in upright silos. Other studies indicated variation in percentages (losses −, gains +): dry matter, −2 to +18 per cent; protein +5 to −38; fat +49 to −20; ash +12 to −16; carbohydrate −6 to −23; and crude fiber +7 to −15.

According to LeClerc,[10] "under ideal conditions of field curing, the differences in feed value between hay and silage is not appreciable."

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Topics for Discussion

1. Is there any gain in total feeding value obtained by placing green forage in a silo?

2. Will any crop commonly grown in your locality produce more total digestible nutrients per acre than a silage variety of corn?

3. Is immature forage as good as riper plants for silage purposes?

4. What prevents the rotting of green crops in the silo?

5. Why has the practice of ensiling grasses and small grains become more popular?

CHAPTER XVI

PASTURE AND MEADOW MANAGEMENT

Pastures and meadows are expensive to seed, and the money loss, in event of failure, is an item of importance. Although the chances of failure are greater in seeding these crops than with many other farm crops, it is unquestionably true that many of the failures can be attributed to poor judgment in seeding or an unwise choice of seeding practices rather than to unavoidable causes.

FIG. 25. A permanent pasture of Kentucky bluegrass, timothy, alsike, and white clover being grazed in Kent County, Maryland. (*U.S. Dept. Agr. Extension Service.*)

PASTURE MANAGEMENT

Although livestock production is vitally dependent upon pastures, little progress in better pasture methods has been made. Until recently, ideas in regard to pasture management in the United States have been based on results of observations rather than on results of actual experimentation. During the First World War a system of intensive pasture management was developed at Hohenheim, Germany, by Professor Warmbold. This greatly stimulated interest in pasture investigation in this country, and at present many of our experiment stations have extensive pasture-management projects under way.

Kinds of Pastures. According to Piper,[1] a pasture may be defined as a field or area covered with grass or other plants (commonly herbaceous) and used for grazing animals.

FIG. 26. A good pasture being grazed on a farm in Washington County, Vermont. (*U.S. Dept. Agr. Extension Service.*)

A classification of pastures, according to Piper, is as follows:

1. Permanent
2. Temporary { Seedling, Stubble, Crop }
3. Rotated
4. Aftermath

A *permanent* pasture is one covered with perennial or self-seeding annual plants, and such pastures are kept for grazing indefinitely. The bluegrass, Bermuda, and lespedeza pastures are good examples of permanent pastures. *Temporary* pastures are those used for grazing during a short period, not more than one crop season. For such pastures, crops such as rape, rye, cowpeas, millet, sweet clover, and Sudan grass are used. A *seedling* pasture refers to a field of wheat, rye, and so forth, in which animals are placed to graze on the young growth. A *stubble* pasture refers to a harvested field of wheat, corn, etc., in which animals are placed to consume the crop refuse and weeds. A *crop* pasture refers to one on which the crop is allowed to mature before the animals are

turned in. Under this head are included fields of such crops as corn, soybeans, and velvet beans, which when matured are utilized as pastures for hogs, sheep, cattle, and other kinds of livestock. If a crop pasture is pastured by hogs, it is said to be *hogged off*. A *rotated* pasture is one used for a few years, usually 2 or 3, and then plowed, in order that crops may be planted. *Aftermath* pasture refers to the second growth on a harvested meadow.

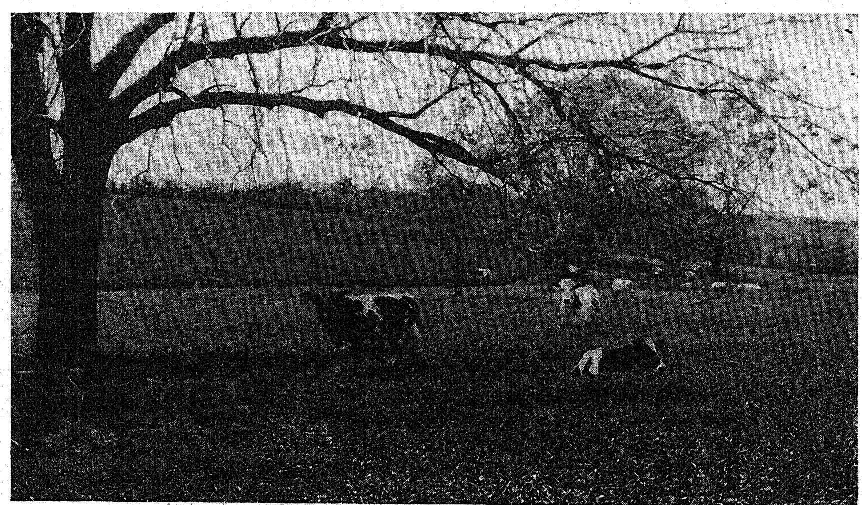

FIG. 27. A temporary pasture of common oats which was planted to meet an emergency on a dairy farm in Shawnee County, Kansas. (*U.S. Dept. Agr. Extension Service.*)

In addition to the foregoing kinds of pastures may be mentioned *tame* and *wild* or *native* pastures. The former are those covered with domesticated grasses and other plants, and the latter are those areas covered with native plants useful for grazing; when extensive, such areas are called *ranges*.

Permanent pastures require much less work and much less fence than rotated pastures. Rotated pastures usually carry more livestock per acre, and, as lands become more valuable, it may pay better to rotate pastures. In all parts of the United States, however, farmers generally use their poorer lands for pasture instead of pasturing the rotated fields.

Permanent pastures may at times be supplemented by pasturing other fields, but there is no very important dairying or meat-producing section in America that does not depend primarily on pastures that last many years. In the northeastern part of the United States, Kentucky bluegrass is the great pasture plant. In the arid regions the native grasses furnish pasture on land that is too dry to farm.

Pastures may also be classified according to the type of forage plants predominating in them such as bluegrass, Bermuda grass, or alfalfa.

Through the use of a combination of the different kinds of pastures, adequate grazing can be provided over a longer period than when only one kind is used, as shown in Fig. 28 (Cardon and others[2]).

Importance of Pastures. More than half of the total feed consumed by livestock in this country is furnished by pasturage. The estimated cost of pasturage is less than one-half as much as harvested forage; there-

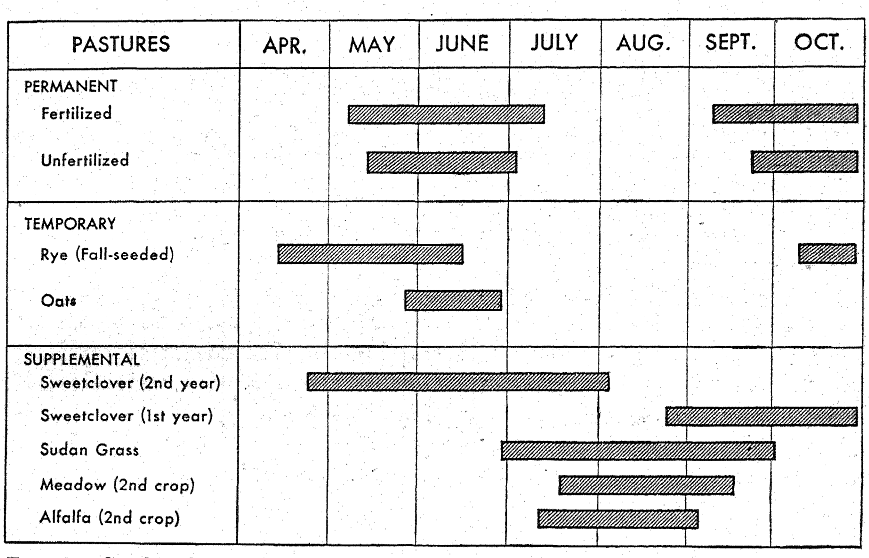

FIG. 28. Combined use of permanent, temporary, and supplemental pastures designed to provide adequate grazing throughout the season. (*U.S. Dept. Agr. Yearbook*, 1939.)

fore pasturage constitutes the only really cheap feed (Semple and Hein,[3] and Semple and others[4]).

Livestock workers are agreed that cattle, horses, and sheep are generally not profitable without pastures, and that even hog production is more profitable where good pastures can be had. Under certain conditions other methods of handling cattle, such as soiling, may be profitable, but these cases are few and usually depend for their successful operation upon an exceptionally high price for products sold or upon very cheap labor. There are no great livestock-producing sections without pastures, and pasturage will probably always be one of the most important factors in economic livestock production.

Essential Qualities of Pastures. It is generally desirable that pastures be made as enduring as possible. Permanency of pasturage calls for a mixture of grasses that are either very long lived or that are

capable of reproduction under pasture conditions. A good pasture should start growth early in the season and continue to produce until late in the fall. Not only should the grasses be palatable and nutritious, but they should present variety and give abundant growth. They should also form a continuous, compact turf that will withstand much trampling by animals. A variety of plants that will provide for growth under both moist and dry soil conditions is also advantageous. The deep-rooted grasses and clovers can, therefore, be advantageously included with the shallow-rooted ones such as bluegrass and white clover. No single grass can make an ideal pasture. Kentucky bluegrass and Bermuda grass more nearly approach ideal pasture grasses in their respective localities than any of the other single grasses, but even these have their periods of low production, and mixtures of other plants that will serve as supplements during short periods are advantageous.

Treatment of Pastures. The treatment of pastures should vary with the type of pastures and to a certain degree with the kind of animals pastured.

Grazing. Jardine[5] states that the most common causes of deterioration in the native Western pastures are overstocking and premature grazing. Lack of well-distributed watering places often causes too heavy grazing and trampling in areas near such places. Jardine suggests, as a means of improving these pastures, the following: (1) Avoid grazing any of the pasture while the land is wet in the spring and when the principal forage plants are just beginning growth. (2) Limit the animals to the number it is believed the whole area will support in good condition for feeders. (3) Keep animals from certain areas each year until after the forage plants have seeded. (4) Control and distribute the stock by fences, well-distributed watering places, and salt troughs so as to minimize congregation in large herds. (5) Watch the vegetation on the area as a whole to find out whether the best forage plants are increasing or decreasing, and increase or decrease the number of animals as may be necessary to bring the pasture, or each division of it, to its maximum production. These suggestions refer especially to bunch grasses.

Cotton[6] states that in New York and New England dairy pastures depreciate much more rapidly than beef pastures. He attributes this depreciation of dairy pastures to the fact that dairy pastures are more often overstocked and advises against turning cattle on pastures in the spring until the pasture will give a full feed without other forage supplement.

The fact that more plant nutrients are removed from the soil when dairy products are taken away than when beef is sold, according to Cotton,[6] may also account for the more rapid depreciation of dairy pastures. It would seem that it is more important for the dairyman to

give attention to keeping up the productivity of his pastures than it is for the beef producer. It is a common belief among beef producers that young growing cattle are harder on pastures than mature cattle. This belief may be based on the fact that young cattle assimilate more of the mineral matter of their feed than do mature cattle.

As the result of pasture experiments conducted at the Virginia Experiment Station on a limestone soil and on a bluegrass-redtop sod, Carrier and Oakley[7] found that: (1) Very little benefit was derived from cultural treatment by disking and harrowing, and this practice could not be recommended. (2) Heavy grazing gave 1,485 pounds of gain on 2.5 acres of land in 3 years. Light grazing gave 838 pounds of gain in the same time on an equal area. At the close of the 5 years' experiment the heavily grazed field had a more even turf and was much freer from weeds than the lightly grazed field. (3) Very little advantage was secured by grazing cattle in different fields alternately as compared with continuous grazing on the same field.

Since heavy grazing is not practicable on pastures used for finishing fat cattle, these authors recommend that pasture areas most densely weed infested be grazed closely with young cattle or sheep for 2 or more years until the sod has improved. It would seem that under the conditions of these experiments heavy grazing is preferable to light grazing, but overstocking should be avoided. Land may be said to be overstocked if the animal cannot get sufficient feed from it to give or keep up production. If overstocking is kept up too long, there is not sufficient leaf and stem growth remaining to maintain the life processes of the plants. As a result many of the bunch grasses are killed, but overstocking does not injure the stand of creeping grasses. Overstocking is evidenced by the increased growth of weeds and by the dying out of those economic plants most palatable to animals.

Fertilizing. Vinall and others[8] state, "A judicious use of commercial fertilizers is generally recognized as the most effective way of increasing the productiveness of established pastures. Fertilizer benefits the pasture in several ways: (1) by lengthening the grazing season, (2) by changing the botanical and chemical composition of the plant populations, (3) by increasing the palatability of the pasturage, and (4) by stimulating or increasing the growth of the herbage."

Woodward and others[9] report that, in fertilizing pastures, applications of superphosphate alone are usually the most profitable because it costs less than other commercial fertilizers and encourages the growth of legumes that supply nitrogen to the grasses. Usually, also, other fertilizers, lime, and barnyard manure may be used most profitably.

In Pennsylvania,[10] the use of fertilizer and lime has been very effective in restoring grass to idle land.

It would appear from the data available that fertilization, reseeding, judicious grazing, weed control, and harrowing to spread droppings are essential practices in a pasture-improvement program. The fertilization will depend upon the type of soil, the nature of the pasturage, and the degree of intensity of all improvement treatments, which must vary with the value of the product being produced.

Seeding Pastures. When seeded on arable land, pasture grasses may be sown just as meadow grasses. However, one of the most common

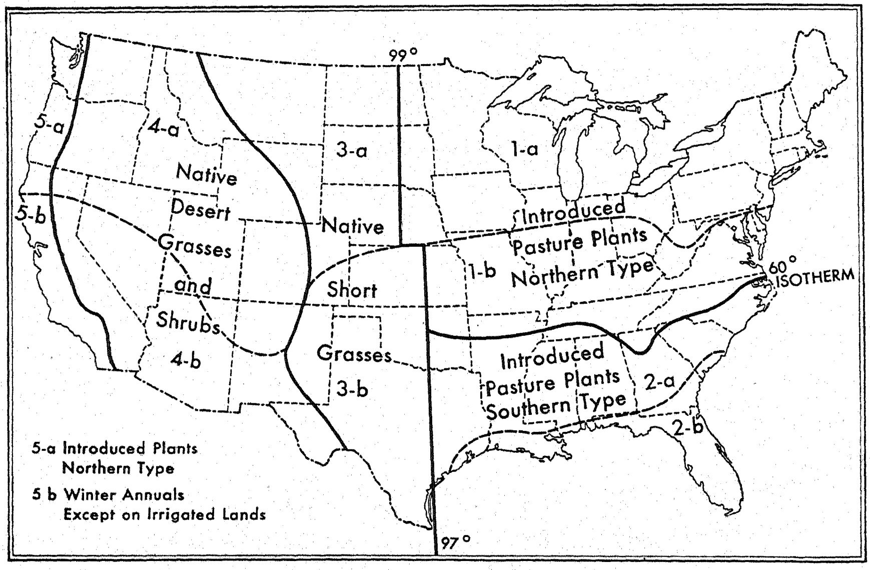

FIG. 29. Map showing types of pasture plants that provide the majority of the pasturage in each part of the United States. (*U.S. Dept. Agr. Misc. Pub.* 194. 1942.)

ways of seeding pasture grasses is to sow them with a meadow mixture, and after hay has been cut for 1 or more years, to use the land for pasture. This method is used because some of the best pasture grasses are slow in growth and do not make a complete sod for several years.

Rough, untillable lands sufficiently good to produce pasture grasses may be seeded by sowing suitable seeds on them early in the spring or, preferably, in the late summer. All brush, shrubs, and leaves should be either burned or removed from the area to be seeded, and the grass mixture seeded without other preparation. The seed should then be disked or harrowed into the soil if the land is clean enough to allow passage of the implement.

Pasture Regions and Plants. Semple and others[4] have divided the United States into five pasture regions in keeping with the different climatic relations of pasture plants (Fig. 29).

The grasses most commonly used in permanent pasture mixtures in the humid areas of the Northern states are brome grass, Canada bluegrass, Kentucky bluegrass, meadow fescue, orchard grass, perennial rye grass, redtop, tall meadow oat grass, and timothy. In the more arid regions the grasses used are brome grass, crested wheatgrass, and slender wheat grass.

In the South the most commonly used grasses are Bermuda, carpet, and Dallis. Those less frequently used in pastures are Johnson, Rhodes, Napier, rescue, and Vasey grasses.

Further information regarding grasses for permanent pastures is given in Table 14.

The legumes that, alone or in combination with the grasses listed in Table 14, are most generally used for making permanent pastures are shown in Table 15.

Rates of Seeding. The rates of seedings of pasture are usually in excess of seedings for meadows. The amounts per acre of each grass and legume included in the pasture mixture may vary, depending on the kind of seed and the condition under which it is seeded. The total amount per acre usually is from 15 to 30 pounds.

A mixture recommended by Semple and others[4] for irrigated lands of the northern part of the Great Plains and Intermountain Regions is as follows:

	Pounds per Acre
Smooth brome grass	9
Orchard grass	9
Timothy	4
Meadow fescue	5
Yellow sweet clover	3
Total	30

Where Ladino clover thrives, a good pasture mixture is 10 to 12 pounds of orchard grass and 2 pounds of Ladino clover per acre. Timothy may be used in place of orchard grass at the rate of 6 pounds per acre.

A good mixture for good well-drained soils of the Northeastern states is as follows:

	Pounds per Acre
Kentucky bluegrass	5–6
Orchard grass	4–5
Timothy	4–5
Redtop	2–3
Alsike clover	2–3
Red clover	2–3
White clover	1–2
Total	20–27

TABLE 14. INFORMATION REGARDING GRASSES FOR PERMANENT PASTURES

Name	Climatic adaptation*	Degree of palatability	Season for grazing	Time and rate of seeding per acre, lb.	Soil adaptation†	Remarks
Bahia grass (*Paspalum notatum*).	Section 2-*b*	High	Early spring to late fall	Early spring, 10–15	Sandy loam to sand	Seed expensive and of low germination
Bermuda grass (*Cynodon dactylon*).	Region 2 and section 3-*b* and 4-*b*	Medium	Late spring to early fall	Early spring, 5–8	Loams, clays, and silts	Propagated to a large extent vegetatively
Brome grass or smooth brome (*Bromus inermis*).	Western part of section 1-*a* and sections 3-*a* and 4-*a*	High	Very early spring to late fall	Early spring or early fall, 15–20	Practically any type	Excellent grass for use with alfalfa
Canada bluegrass (*Poa compressa*).	Region 1-*a* and sections 3-*a* and 4-*a*	High	Early spring to late fall	Early spring or fall, 15–20	Almost any type	Succeeds on poor soils
Carpet grass (*Axonopus compressus*).	Region 2	Medium	Spring to fall	Early spring, 8–12	Moist sands or sandy loam	Makes a very tight turf
Centipede grass (*Eremochloa ophiuroides*).	Southern half of region 2	Medium	Spring to fall	Early spring; use sod or stolons; no seed available.	Almost any type	Makes a close turf and is very aggressive, when once established, crowding out weeds, legumes, and other grasses
Crested wheat grass (*Agropyron cristatum*).	Sections 3-*a* and 4-*a*	High	Very early spring to late fall	Early spring, 12–15	Almost any type	Drought resistant; easy to get a stand
Dallis grass (*Paspalum dilatatum*).	Region 2 and sections 3-*b*, 4-*b*, and 5-*b* where irrigated	High	Early spring to late fall	Early spring or fall, 8–12	Any fairly productive soil	Seed expensive and often of low germination; difficult to get a stand
Johnson grass (*Sorghum halepense*).	Region 2 and section 3-*b*; also 4-*b* and 5-*b* where irrigated	High	Spring to fall	Early spring, 20–25	Loams and clays	Productiveness decreases rapidly when grazed; very difficult to eradicate
Kentucky bluegrass (*Poa pratensis*).	Region 1 and section 5-*a*; also 3-*a* and 4-*a* where moisture is plentiful	High	Spring to late fall	Early fall, 15–20	Sandy loams to clays of high productivity	The leading pasture grass on good soils in the North
Meadow fescue (*Festuca elatior*).	Region 1 and section 5-*a*; also 3-*a* and 4-*a* where moisture is plentiful	High	Early spring to late fall	Early fall, 20–25	Loams to heavy clays	Valuable in section 5-*a*; of limited value elsewhere, disappearing rather quickly except on heavy, moist clays
Meadow foxtail (*Alopecurus pratensis*).	Sections 1-*a* and 5-*a*; also 4-*a* at high altitudes	High	Early spring to late fall	Early fall, 20–25	Moist sandy loams to clay	Very useful in pasture mixtures on wet soils, especially in 5-*a*.
Orchard grass (*Dactylis glomerata*).	Region 1; also sections 3-*a*, 4-*a*, and 5-*a* where moisture is plentiful	Medium to high	Early spring to fall	Early fall or early spring, 20–25	Any soil type except sand, if not too wet	Inclined to grow in bunches unless seeded thickly
Para grass (*Panicum purpurascens*).	Section 2-*b*	High	Spring to fall	Early spring, no seed available	Wet soils	Propagated by planting pieces of stem or sod
Perennial rye grass (*Lolium perenne*).	Southern half of region 1 and in section 5-*a*	High	Early spring to late fall; winter grazing in section 2-*a* to limited extent	Very early fall (or spring in the North), 20–25	Sandy loams to clays of medium to good fertility	Used but little in pasture except in section 5-*a* and New England States

TABLE 14. INFORMATION REGARDING GRASSES FOR PERMANENT PASTURES—(*Continued*)

Name	Climatic adaptation*	Degree of palatibility	Season for grazing	Time and rate of seeding per acre, lb.	Soil adaptation†	Remarks
Redtop (*Agrostis alba*).	Regions 1, 2, and section 5-*a*; also under irrigation and in mountain meadows, sections 3-*a* and 4-*a*	Medium	Early spring to late fall	Early fall best, early spring fair, 10–12	Grows on majority of soil types; prefers moist soils	Of most value on poorly drained soils too wet for other grasses
Reed canary grass (*Phalaris arundinacea.*)	Sections 1-*a* and 5-*a*; also 3-*a* and 4-*a* where moisture is plentiful	Medium	Spring to fall	Very early spring, 8–12	Loams to heavy clays	Very good for wet lands, will endure submergence
Rescue grass (*Bromus catharticus*).	Region 2, and where moisture is sufficient in sections 3-*b* and 4-*b*	Medium	Fall to spring (winter pasture)	Early fall, 20–25	Sandy loam to clay loam	An annual, used in some localities for winter and spring grazing
Rhodes grass (*Chloris gayana*).	Section 2-*b*; also southern parts of 3-*b* and 4-*b*	Medium	Spring to fall	Spring, 10–12	Loams to clays	Found most useful in the dry sections of southern Texas where other grasses fail
Slender wheat grass (*Agropyron pauciflorum*).	Northern parts of sections 3-*a* and 4-*a*	High	Early spring to late fall	Early spring, 15	Practically any type, except sand	Better for hay than pasture; inclined to be stemmy
Tall oat grass (*Arrhenatherum elatius*).	Sections 1-*b* and 5-*a*	Medium	Early spring to late fall	Early fall, 20–25	Practically any type, except sand	Better in hay mixtures than for pasture; stemmy; used most for pasture in section 5-*a*
Timothy (*Phleum pratense*).	Region 1 and section 5-*a*; also 3-*a* and 4-*a* where moisture is sufficient	High	Early spring to late fall	Early fall (or early spring), 12–15	Practically any type, except sand	Comes quickly and furnishes much pasturage at first, but is not permanent

* The region and section numbers refer to those in fig. 29.
† Specifications of soil types in this and the following tables are necessarily very general because of space limitations.

TABLE 15. INFORMATION REGARDING LEGUMES FOR PERMANENT PASTURES

Name	Climatic adaptation*	Degree of palatability	Season for grazing	Time and rate of seeding per acre, lb.	Soil adaptation†	Remarks
Alfalfa (*Medicago sativa*) . . .	All regions where moisture is sufficient, but only locally in region 2	Very high	Spring to early fall. Winter grazing in Southwest when irrigated	Depends on location; consult state experiment station	Practically any fertile soil not wet or acid	Good pasture, but danger of bloat. Use locally adapted seed
Alsike clover (*Trifolium hybridum*).	Chiefly region 1 and section 5-*a*. In sections 3-*a* and 4-*a* if moisture is sufficient. Winter crop in region 2	Very high	Early spring and fall	Early spring, 8–10	Practically any soil type except sands. Will stand slight acidity and will tolerate some inadequate drainage	Especially suited for wet land
Red clover (*Trifolium pratense*).	Chiefly region 1 and section 5-*a*. In sections 3-*a* and 4-*a* if moisture is sufficient	Very high	Early spring to fall	Early spring, 10–15	Practically any well-drained soil if not acid	Use locally adapted seed
Mammoth red clover (*Trifolium pratense* var.).	Region 1, chiefly section 1-*a*	High	Early spring to fall	Early spring, 10–12	Practically any well-drained soil not more than slightly acid	Will endure slightly more soil acidity than common red
White clover (*Trifolium repens*).	All regions where moisture is sufficient	Very high	Early spring and fall	Very early spring, 5–10	Practically any soil type	Everywhere in the North. In region 2, winter and spring crop
Ladino clover (*Trifolium repens* var.).	Sections 4-*a*, 5-*a*, and 5-*b*	Very high	Spring to fall	Early spring, 5–10	Practically any well-drained, well-watered soil	Injured by heavy continuous grazing
Least hop clover (*Trifolium dubium*).	Sections 2-*a* and 5-*a* and parts of section 1-*b*	High	Spring	Late summer, 4–5	Good soil	Annual; disappears in June; volunteers
Low hop clover (*Trifolium procumbens*).	Section 2-*a* and southern part of section 1-*b*	High	Spring	Late summer, 4–5	Practically any well-drained soil	Annual; usually disappears in June but volunteers
Strawberry clover (*Trifolium fragiferum*).	Locally in sections 3-*a*, 4-*a*, and 5-*a*	High	Spring to fall	Early spring, 5–10	Wet alkali soil	Grown only locally; domestic seed produced in Oregon

TABLE 15. INFORMATION REGARDING LEGUMES FOR PERMANENT PASTURES—(*Continued*)

Name	Climatic adaptation*	Degree of palatability	Season for grazing	Time and rate of seeding per acre, lb.	Soil adaptation†	Remarks
Sour clover or annual melilot (*Melilotus indica*).	Region 2 and sections 3-*b*, 4-*b*, and 5-*b*	Medium	Winter and early spring	Late summer	Sweet well-drained soil	Annual; volunteers; no value north of region 2
Yellow trefoil or black medic (*Medicago lupulina*).	Region 2 and section 1-*b*	Very high	Early spring to late fall	Very early spring, 8–12	Sweet well-drained soil	Not prominent, except on black land in Alabama and Mississippi
California bur clover (*Medicago hispida*).	Sections 3-*b*, 4-*b*, and 5-*b* if sufficient moisture, also eastern Texas and Oklahoma	High	Fall to spring	Late summer, 15–20 hulled seed	Well-drained soil of practically any type	A winter annual; volunteers
Southern bur clover (*Medicago arabica*).	Region 2 and section 3-*b*	High	Fall to spring	Late summer, 10–15, hulled seed	Well-drained soil	Annual, but reseeds
Common lespedeza (*Lespedeza striata*).‡	Region 2 and section 1-*b*	High	Early summer to fall	Early spring, 20–25	Well-drained soil	Annual, but is usually permanent in pastures because of volunteer seeding
Korean lespedeza (*Lespedeza stipulacea*).	Section 1-*b*	High	Early summer to fall	Early spring, 20–25	Practically any well-drained soil	Annual, but volunteers

* Region and section numbers refer to Fig. 29.
† See footnote 2, Table 14.
‡ Kobe and Tennessee 76 are heavy-yielding strains of common lespedeza that should be used in region 2 and the southern part of section 1-*b*.

Garber and others[11] found that a mixture of Ladino clover, alfalfa, orchard grass, and brome grass is an excellent mixture for the Northeastern states.

Carrying Capacity of Pastures. No definite statement can be made as to the carrying capacity of pastures. This will depend upon soil, climate, and season. The average carrying capacity will vary from 5 to 20 acres per animal unit on the ranges of the Southwest and the cutover pine lands of the South to less than 1 acre per animal unit on some of the productive bluegrass and white clover, and Ladino and orchard grass pastures of the North. In the bluegrass section of Kentucky it is a common practice to estimate 3 acres of good bluegrass pasture per steer when animals are to be fattened on pasture, and, if the pastures are short, 5 to 6 acres of land are often allowed for each fattening steer. When the cattle are not to be finished on pasture, 2 acres of good pasture should be sufficient for an animal unit.

The Hohenheim System of Pasture Management. The four main points involved in the Hohenheim system are (1) dividing the pasture area into several smaller areas, (2) dividing the grazing herd according to production, (3) frequent rotation of these groups of cattle, and (4) intensified fertilization with more attention to high nitrogen applications. Although there is nothing new about rotating cattle from one field to another or manuring pastures and dividing them into smaller fields, it is claimed that the combination of these, practiced systematically, produces results never before attained in pasture management. The chief aim of the system is to keep the producing herd grazing on a plentiful supply of tender, nutritious grass that is high in protein and rich in minerals.

In operating the system, the fields are limed and given a base treatment of 50 to 70 pounds of phosphoric acid and a like amount of potash. During the growing season, the pastures are top-dressed with 80 to 100 pounds of nitrogen from some readily available source in two or more applications. The pasture is divided into three or more fields, and the producing herd is turned into the first field as soon as there is an abundance of tender grass available. They remain in this field for a few days and are then changed to the next field, while dry cows and young cattle are turned into the first field to clean up what is left. This process is continued until all fields have been grazed and is then begun again. As soon as the nonproducers are removed from a field, the pasture is harrowed to scatter the droppings, and more fertilizer is applied if deemed necessary. The cost of fertilizer, additional fencing, application of fertilizer, and harrowing, under this system, will usually amount to $25 or more per acre. It is obvious that it is not practicable except for high-

producing animals, where dairy products sell for a relatively high price. However, modifications of the system that entail less expense are being followed by many practical dairymen.

Woodward and others[9] report that rotation grazing increased the yield of total digestible nutrients 10.4 per cent; heavy fertilization, 16.4 per cent; and both rotation grazing and heavy fertilization combined, 28.6 per cent.

MEADOW MANAGEMENT

Tbe term "meadows," as used in this discussion, refers to lands devoted to crops that are to be made into hay. Formerly this term was applied only to lands that were too low and wet for the production of cultivated crops, but more recent writers use it for all hay lands wherever found. The plants most commonly used for meadows are alfalfa and the true grasses and clovers. However, many plants of other species are used for hay. All such plants are generally spoken of collectively as "grass," and the lands on which they are grown as "grasslands."

Duration of Meadows. Meadows may be permanent or temporary in duration. When the meadows are permanent the lands are seldom or never plowed. Temporary meadows are frequently allowed to remain 1 to 4 years, and usually as a part of the crop rotation.

Value in Rotation. Meadows constitute the cheapest source of dry forage for livestock and for this reason occupy an important place in the agriculture of the country. In rotations they (1) reduce erosion, (2) form a sod that is favorable to the fixation of nitrogen in the soil, and (3) increase the humus supply of soil. All these functions are extremely important. Probably more nutrients are lost from the soil by erosion than by cropping. When meadows occupy an important place in the rotation, the roots of the grasses hold the soil together and reduce the amount of runoff water. It is a common observation that those sections of our country where grasses do not occupy an important place in agriculture suffer most from the effects of erosion.

Since some meadows contain clovers or other legumes, they offer a favorable condition for nitrogen fixation, and, when the sod is turned under, much organic matter from the roots and crop residues is added to the soil. Farmers generally recognize the soil-improving properties of a sod turned under.

Meadow Plants and Their Importance. The average annual value of hay produced in the United States during the 10-year period 1928–1937 was about 765 million dollars, more than that of any other crop except corn (Woodward and others[12]).

During the same period, the most important crops used for hay, based on average tonnage per year, were (1) all clover and timothy, (2) alfalfa, (3) wild hay, (4) soybeans, cowpeas, and peanut vines, (5) small grains, (6) sorgo, (7) lespedeza, and (8) sweet clover. During the 10-year period the tonnages of alfalfa, soybeans, and lespedeza increased and those of timothy and clover and wild hay decreased. However, for the 3-year period 1935–1937, the ranking remained the same, except that alfalfa was named ahead of all clover and timothy.

Methods of Seeding. There are three principal methods of seeding land to grass: (1) spring seeding with a nurse crop, (2) late summer or early fall seeding without a nurse crop, and (3) seeding in corn or other cultivated crops at the last cultivation.

Spring Seedings. Spring seeding with a nurse crop is the most common method of seeding rotated meadows. In this method the seeds are sown on small-grain fields early in the spring. In case the nurse crop is a fall-seeded grain, the grass and clover seeds are sown as soon as all danger of soil freezing has passed. When the seeds are sown on spring-seeded grain fields, the seeding is done at the time the grain is sown; on good lands and in seasons when there is an abundance of moisture in the spring and early summer, such seedings grow off well. However, when the soil is thin and the season dry, this method often results in failure to obtain a stand. On the thinner soils the young grass is seriously weakened and sometimes entirely destroyed by exposure to the hot sun when the nurse crop is removed. This method is sometimes modified by sowing the more hardy grasses such as timothy and redtop with the grain in the fall and sowing the clover in the spring. When grass and clover seeds are sown on small-grain fields in the spring, they should always be covered. A light smoothing harrow is a good implement to use for this purpose. The harrowing does not injure the grain crop and reduces the chances for a poor stand of grass and clover. Seeds sown on fields without covering catch if seasonal conditions are right, but often the plants die on account of insufficient moisture.

Late Summer and Fall Seedings. Late summer and fall seedings usually give splendid results except in sections where protracted droughts commonly occur at these seasons of the year. If clovers are used in the mixture such seedings should be made at least 30 days before the first killing-frost date of the section. If no clover is sown, seedings may be delayed for 2 weeks; but even then in most cases the earlier seedings will give better results. In cases where clovers are desired in the mixture and seedings have been delayed, the grasses may be seeded in the fall and the clovers sown early in the spring.

Good soil preparation is essential to success when late summer and early fall seeding is practiced. Either the land should be plowed and

subsequently disked and harrowed until a good seedbed is formed, or it should be disked thoroughly to the depth of at least 3 inches in order to form a finely pulverized seedbed.

Seeding in Cultivated Crops. Seeding in corn has given good results in many sections where the corn is cultivated level and kept free from weeds. Where this method is followed, the corn should be given a thorough cultivation in order to pulverize the soil before seeding the meadow mixture. The seeds should then be covered by running a fine-toothed cultivator between the rows of corn. This method gives best results on rich soils in sections where rain is abundant in the latter part of the summer.

Reseeding Permanent Meadows. All permanent meadows finally begin to deteriorate, and it usually pays to reseed them after they have been down 3 to 5 years. Brooks[13] states that at the Massachusetts Experiment Station a portion of a permanent meadow was plowed and reseeded in the summer. The following year the yield on the portion reseeded was 8,546 pounds of hay to the acre, while that on the plat which was not reseeded was only 6,243 pounds to the acre.

When permanent meadows are to be reseeded, probably the best procedure is to plow the land as soon as possible after the crop is harvested and work it down by repeated cultivations until time for summer seeding. The seed should then be sown without a nurse crop.

Meadow Mixtures. Unless hay is grown for a market that demands unmixed hay of a particular variety, it will be found more profitable to sow mixtures of several grasses and clovers than to sow only one kind. The reasons often assigned for this are as follows: (1) the roots of different plants occupy different portions of the soil; (2) mixed hays supply a variety of feed and usually give a better balanced ration than a single kind; (3) most fields are uneven in productivity and other soil conditions, and no one plant is particularly adapted to all the conditions that usually exist in a field; (4) loss by insects or diseases may be lessened; and (5) legumes may aid the growth and increase the protein content of the non-legumes in the mixture.

Examples of Meadow Mixtures. A number of mixtures that have given good results in various localities are as follows:

1. The standard mixture for the timothy region is timothy and mammoth red clover. Frequently redtop is added to this mixture; and where mammoth clover fails, it is often replaced by alsike clover.
2. Orchard grass, tall oat grass, and alsike clover do well on the thinner soils of the timothy regions.
3. Redtop, alsike clover, and meadow fescue are suited to low wet lands.
4. For semihumid regions, the mixtures recommended are brome grass and timothy or brome grass and orchard grass.

5. Where alfalfa thrives it makes good mixtures with timothy, Johnson grass, brome grass, and tall oat grass.

6. Where Bermuda grass is used for hay, it makes a good mixture with lespedeza.

As a rule the ratio of the amount of seed for different species entering into a meadow mixture will be a little larger than when the plants are seeded alone. For example, when timothy, clover, and redtop are seeded alone, 15, 12, and 6 pounds, respectively, would be considered a reasonable rate of seeding. When seeded together, 10 pounds timothy, 8 pounds clover, and 4 pounds of redtop, a total of 22 pounds of seed to the acre, would be required.

Fertilizers for Meadows. The greater part of the hay produced in the United States is grown in rotation, and, if fertilizers are used at all, they are usually applied to other crops in the rotation. However, there is an abundance of experimental evidence to indicate that the hay crop responds well to the use of fertilizers and that their use on the hay crop is profitable in sections where the product has a fair market value.

Jones and others[14] report that the yield of orchard grass hay from land receiving no nitrogen fertilizer was 1,099 pounds to the acre, and from that receiving 100 pounds of nitrogen to the acre, 5,099 pounds. Not only did the nitrogen increase the yield, but also the protein content of the hay.

The use of borax on alfalfa frequently results in increased yields, less leaf yellowing, greater production of seed, longer life of stands, and higher production of protein, according to Dunklee and Midgley.[15] Similar results were secured by Hutcheson and Cocke.[16]

The borax is usually mixed with the fertilizer, and the two applied together. The rate of application of borax varies, but it is generally from 10 to 20 pounds per acre.

Cultural Treatment for Meadows. Cultivation of meadows is sometimes recommended to increase yields, but, if timothy and clover are the chief plants in the meadows, cultivation is of a doubtful value. It would probably be better to plow such meadows and reseed.

In the case of alfalfa, early spring cultivation with a spike-tooth harrow or a special implement made for the purpose is recommended. These implements remove some weeds and seem to stimulate the growth of the alfalfa. Meadows consisting of Johnson grass and Bermuda grass have a tendency to become sod bound, and when this is the case they may be greatly improved by cultivation. The harrowing of such fields early in the spring before growth starts greatly increases the yield of hay. In certain cases such meadows may be renewed by putting the land in a cultivated crop for one season. The stand of grasses is not

greatly reduced by the cultivation, and the breaking up of the sod increases the vigor of the plants.

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Topics for Discussion

1. What are the most common causes of pasture deterioration in your locality?
2. What is the most common cause of weeds and undesirable plants in pastures?
3. Is it ever desirable to graze pastures heavily?
4. What are important considerations in making a meadow mixture?

CHAPTER XVII

WEEDS

A weed may be defined as "a plant out of place." It follows that a plant may be a weed in some places and not in others. For example, Bermuda grass, which is considered one of the most noxious weeds in places where it is not desired, in certain parts of the South is the most valuable pasture grass. Some plants are considered weeds wherever they grow, as they do not seem to serve a useful purpose anywhere. However, some of our most useful plants have been considered worthless weeds in the past, and use may yet be found for many plants that we now consider pests. As late as 1893, laws were passed in Wisconsin to prevent the spread of sweet clover, which was classed with Canada thistle as a weed pest.

In 1859, William Darlington made the following statement: "The labors of the agriculturist are a constant struggle. On the one hand, by presenting the most favorable conditions possible, he endeavors to make certain plants grow and produce to their utmost capacity; on the other hand, he has to prevent the growth of certain other plants that are ready to avail themselves of these favorable conditions."

Loss Due to Weeds. Weeds cause a direct loss to farmers in the following ways: (1) they lower the selling value of the land; (2) they reduce crop yields; (3) they increase the expense of cultivation and harvest; (4) they reduce the market value of crops; (5) they harbor fungi and insects that attack adjacent crops; and (6) in certain cases they poison or otherwise injure man, livestock, or livestock products.

Reduction in Selling Value. Lands overgrown with weeds of certain kinds practically always sell for a lower price per acre than similar lands that are free from these pests. In certain sections lands have been greatly reduced in price by invasion of such weeds as quack grass, Johnson grass, and Canada thistle. Because of the increased difficulty of cultivation, such lands are not worth as much as weed-free land and should therefore justly sell for a lower price.

Reduction in Yield. Examples of reduced yields due to weeds are common. All plants require a certain amount of nutrients, water, and space for growth, and when crowded they cannot thrive. If the space

needed for their development is to any extent occupied by weeds that rob the cultivated plants of nutrients, moisture, and sunlight, the returns from the crop must be correspondingly less.

Hutcheson. Hodgson, and Wolfe[1] allowed weeds to grow in one plat of corn, and on an adjacent plat they kept all weeds cut close to the surface of the ground. In each case the soil was not stirred after the corn was planted. As a result of a 4 years' test the plat on which the weeds were allowed to grow gave an annual yield of 8.17 bushels of corn to the acre, while that from which the weeds were removed gave an average yield of 49.04 bushels to the acre. This result means a loss of 40.87 bushels of corn to the acre due entirely to the presence of weeds. In this experiment no weeds were removed, but, even when only a few weeds are left in cultivated crops, the yield is correspondingly reduced.

Cates[2] estimated that weeds reduce the yield of corn 10 per cent; tame hay, 3 to 16 per cent; potatoes, 6 to 10 per cent; spring grain, 12 to 15 per cent; winter grain, 5 to 9 per cent; tobacco, fruit, and truck crops, from 0 to 5 per cent; and pasture, 5 to 50 per cent.

Increased Cost of Cultivation and Harvest. The presence of weeds not only decreases yields but also increases the expense of cultivation and harvest. A corn or cotton field infested with Johnson grass or Bermuda grass requires almost twice as much cultivation to ensure a profitable crop as does a field comparatively free from persistent weeds. A field infested with weeds such as cockle, dock, or thistle requires extra labor and causes extra depreciation of machinery in harvest. Also the labor for threshing and cleaning the seed from a weedy crop is much greater than for a clean crop.

Arny,[3] comparing different methods of eradicating quack grass, reported that the cost for the additional labor necessary for the growing of the crop on quack-grass land over that of growing identical crops under good conditions, was, in a 5-year rotation, \$10.10 per acre; in a 4-year rotation, \$8.71; in a 3-year rotation, \$13.45; and in a 2-year rotation, \$8.50. He reported that the expenditure of these amounts for additional labor annually, through the rotation period, resulted in the complete eradication of the quack grass.

Reduction in Market Value. The market value of crops is always greatly reduced by the presence of weeds. The dockage of grain due to weed seeds is a constant source of loss to farmers. Hay containing large quantities of weeds brings very low prices on the market and in most cases is greatly reduced in feeding value. Crops intended for seed suffer a great reduction in price when they contain weed seeds, for such crop seeds must go through an expensive operation of cleaning before they can be marketed, or they must be sold as low-grade seeds.

Harboring of Pests. It is a well-known fact that certain weeds act as host plants for important diseases and insects. Examples of these are clubroot in cabbage, which is fostered on wild members of the mustard family; southern tomato wilt, which will live on ragweed and other succulent plants; septoria leaf spot of tomatoes, which is fostered by horse nettle; and the Colorado potato beetle, which also lives on some of the other members of the nightshade family.

Some Other Effects of Weeds. Certain weeds like poison ivy, jimson weed, and seeds of corn cockle are injurious to man. Others, such as larkspur, water hemlock, and locoweed, are poisonous to livestock and cause considerable loss to stockmen. Wild garlic and bitterweed reduce the price of dairy products by giving them an unpleasant taste.

When to the foregoing is added the loss of pasturage due to the invasion of such weeds as hawkweed, Canada thistle, and sneezeweed, it is readily seen that the damage each year due to weeds in the United States is very great.

Advantages of Weeds. Weeds are not always useless. Often they are the principal means by which organic matter is added to the soil. Weeds contain a large amount of mineral nutrients. When they are returned to the soil, these nutrients become available for more useful plants. They take up soluble plant nutrients on land that is not in cultivated crops and prevent the leaching of these nutrients from the soil. They also afford a covering for waste places and thereby check erosion by water and winds. Weeds may serve another useful purpose because they compel the cultivation of the soil.

However, all these benefits may be obtained where proper rotation is possible, in which case it is not usually economical to permit weed growth.

Classification of Weeds. The habits of life, growth, and propagation of weeds determine the methods of their control. Weeds may be classified into three groups according to their duration or length of life: (1) annuals, (2) biennials, and (3) perennials.

Annual Weeds. Annual weeds are of two kinds: *summer annuals* and *winter annuals.* Summer annuals grow from seed each spring or summer and do not survive the winter. Winter annuals germinate in summer or autumn, live over winter, and mature and die the next year. The annual weeds depend for propagation upon the seeds they produce. Most of the ordinary annual weeds, if well developed, produce from 10,000 to 1,000,000 seeds per plant. These seeds do not all germinate at the same time, but some of them remain viable in the soil for years and come up when conditions become favorable. Arthur[4] reports, as the result of experiments carried on at the Indiana Experiment Station, that from

127 to 489 viable seeds were found to the square foot of field soil 6 inches deep. The smaller number was found in well-cultivated fields and the larger number in fields where weed eradication had been neglected. Annual weeds are comparatively easy to control by cultivation, and, if prevented from seeding, have no means of reappearing except from old seeds in the soil.

Biennial Weeds. Biennial weeds live 2 years. During the first year they grow rather slowly, producing usually a taproot and a rosette of leaves close to the ground; during the second year they send up flowering stems that produce seeds and then die. Such weeds are eradicated by the prevention of seeding and by the destruction of the rosettes that appear in the fall.

Perennial Weeds. Perennial weeds live over winter from year to year either above or below ground. The underground parts besides roots may consist of underground stems, rootstocks, or bulbs. These perennial weeds are often very difficult to eradicate, as when the top is killed the underground parts contain a supply of food material for renewing growth.

In Table 16 is given a description of 25 of the worst weeds of the United States, listed by Cox.[5]

Classification According to Habitat. Weeds may also be classified according to habitat as follows: (1) weeds of cultivated fields, (2) grain weeds, (3) grassland weeds, (4) garden weeds, (5) orchard weeds, (6) lawn weeds, and (7) wasteland weeds. In cultivated fields and gardens the ordinary operations of cultivation are the main dependence for weed control. In grain and grasslands one must depend upon clean seeds and clean cultivation of previous crops. In pastures, mowing, sheep grazing, and spraying small patches of weeds give good results. The weeds of wastelands may be kept under control by mowing and burning. Weeds common to wet lands disappear when the land is drained.

Dissemination of Weeds. Weed seeds are scattered by many agencies. The most common agencies of dispersal are wind, water, animals, wool, cultivation, impure seeds, highways, and peculiar mechanisms of the plant itself.

Many weed seeds are light and easily blown about by the wind; others are equipped with feathery tufts, such as those of dandelions and milkweeds, which enable them to be carried through the air from place to place. A number of very troublesome weeds, such as cockleburs and docks, are carried by water. The seeds of these weeds are washed down to streams by heavy rains and are deposited when these streams overflow.

Wool is responsible for the spread of many weeds. The seeds of some weeds easily catch in the wool when sheep are feeding and are carried

TABLE 16. DESCRIPTIVE LIST OF 25 OF THE WORST WEEDS OF THE UNITED STATES (A. = annual, B. = biennial, P. = perennial)

Common name, botanical name, and duration of life	Color, size, and arrangement of flowers	Sections where injurious	Method of seed distribution; vegetative propagation of the perennials	Place of growth and products injured
Bermuda grass (*Capriola dactylon*), P.	Purple; 1/12 in.; spikes	Maryland to Missouri and southward	Seeds sparingly; rootstocks	Fields and lawns; hoed crops
Bindweed, field bindweed (*Convolvulus arvensis*), P.	White or pink; 1 in.; solitary	Entire United States, especially California	Grain and flax seeds; creeping roots	Rich, moist soils; grain and hoed crops
Chess, cheat (*Bromus secalinus*), A.	Green; spikelets in panicles	All grain sections	Grain seed; especially wheat	Everywhere; grain fields
Chickweed, common chickweed (*Alsine media*), A.	White; 1/8 in.; cymes	Entire United States	Grass and clover seed, animals; has a long seeding period	Meadows, lawns; winter crops
Cocklebur, clotbur (*Xanthium americanum*), A.	Green; 1/4 in.; head	Entire United States	Carried by animals	Cultivated fields and waste places; hoed crops and wool
Crab grass (*Syntherisma sanguinale*), A.	Green; spikes	Entire United States, especially the South	Clover and grass seed, hay, animals	Cultivated fields, gardens, lawns, hoed crops
Dandelion (*Leontodon taraxacum*), P.	Yellow; 1¼ in.; head	Entire United States	Wind; taproot, which spreads but little	Lawns, meadows, waste places; hay and lawns
Dock, yellow dock (*Rumex crispus*), P.	Green; 1/4 in.; panicle	Entire United States	Hay and straw, clover and grass seed; taproot, which spreads but little	Hay, small-grain and hoed crops
Dodder, alfalfa dodder, field dodder (*Cuscuta arvensis*), A.	Yellow; 1/8 in.; clusters	All clover and alfalfa regions	Hay, clover, and alfalfa seed	Clover and alfalfa fields
Hawkweed, orange hawkweed, devil's-paintbrush (*Hieracium aurantiacum*), P.	Orange; 1 in.; heads	Maine to Ohio	Wind, grass, and clover seeds; runners similar to strawberry	Untillable pastures and meadows
Johnson grass (*Holcus halepensis*), P.	Green; 1/8 in.; panicle	Virginia to Texas and California	In hay, grain, and grass seed; running rootstocks	All crops except hay
Lamb's-quarters (*Chenopodium album*), A.	Green; very small; panicle	Entire United States	Grain and grass seed	Grain fields and hoed crops
Lettuce, prickly lettuce (*Lactuca scariola*), A.	Yellow; 1/4 in.; heads in panicles	Ohio to Iowa, Utah to California	Wind	Everywhere; all crops
Mustard, wild mustard, charlock (*Brassica arvensis*), A.	Yellow; 1/2 in.; racemes	Maine to Washington	Grain, grass, clover, and rape seeds	Small-grain fields and meadows; grains
Plantain, buckhorn, rib grass (*Plantagol anceolata*), P.	White; 1/16 in.; spike	Entire United States	Hay, clover, and grass seed; spreads but slowly from a crown	Everywhere; meadows, pastures, and lawns

TABLE 16. DESCRIPTIVE LIST OF 25 OF THE WORST WEEDS OF THE UNITED STATES.—(*Continued*)

Common name, botanical name, and duration of life	Color, size, and arrangement of flowers	Sections where injurious	Method of seed distribution; vegetative propagation of the perennials	Place of growth and products injured
Poison ivy (*Rhus toxicodendron*), P.	Greenish white; ⅛ in.; panicles	Entire United States	Does not spread fast by seeds; running rootstocks	Moist rich land, along fences; poisonous by contact
Quack grass, witch grass (*Agropyron repens*), P.	Green; spike	Maine to Pennsylvania and Minnesota	Seeds of grain and coarse grasses; creeping rootstocks	All crops on the better soils; hoed crops
Ragweed, smaller ragweed (*Ambrosia elatior*), A.	Yellow; ¼ in.; small heads on spikes	Entire United States	Wind carrying matured plants; in grain and red clover seeds	Everywhere, especially grain stubble; hoed crops and young grass seeding
Russian thistle (*Salsola pestifer*), A.	Purplish; ¼ in.; solitary	Minnesota to Washington and southward	Wind rolling matured plants	Everywhere; small grain and hoed crops
Sandbur (*Cenchrus carolinianus*), A.	Green; ⅛ in.; bur	Maine to Florida and westward to Colorado	Animals, especially sheep	Sandy land pastures and waste places; pastures and wool
Sorrel, sheep sorrel (*Rumex acetosella*), P.	Red; ⅛ in.; panicles	Entire United States	In clover seed; creeping roots	Meadows and pastures
Thistle, Canada thistle (*Cirsium arvense*), P.	Purple; ¾ in.; heads	Maine to Pennsylvania and Washington	Wind, in hay and straw and in clover and grass seed; creeping roots	All crops

by them to other localities. Many foreign weeds have been brought into this country in uncleaned wool and have spread from the vicinity of woolen mills.

It is not uncommon for weeds to be carried from place to place by plows and cultivators; Bermuda grass and quack grass are often spread in this manner.

Animals and birds eat the seeds of numerous weeds. These often pass through the digestive system with their vitality unimpaired and are scattered in droppings. Other weed seeds are carried from place to place in the coats of animals.

Highways are an important factor in the distribution of weeds to adjacent fields. Weeds are usually allowed to grow uninterrupted along the roadside, and the seeds so produced are carried by the usual agencies to adjacent fields.

Certain weeds are equipped with peculiar mechanisms that aid in scattering their seeds. Certain species of oxalis have explosive properties that scatter their seeds to considerable distances. Many seeds of leguminous plants are thrown out violently by the twisting action of the bursting pod; other weed seeds, like stickweed, Spanish needles, and cocklebur, have a mechanism for attaching themselves to passing objects and are thus carried from place to place.

Control of Weeds. There are several general methods of weed control. The more common are (1) cultivation, (2) smothering, (3) mowing, (4) pasturing, (5) chemical sprays, (6) crop rotation, and (7) the use of clean seed.

Cultivation. The processes of tillage, by destroying weeds with the hoe, plow, or cultivator, not only kill the living weeds but when done at the proper time prevent the seeds from maturing. Then too, tillage, by stirring the soil, brings deeply buried seeds close to the surface and induces germination, after which succeeding cultivations may kill them. In this manner many weeds may be destroyed in one season.

In some cases weeds may be destroyed by cultivating or harrowing meadowland. This practice is common in some sections, particularly for alfalfa meadows. However, when grasses with creeping rootstocks, such as Bermuda grass, Johnson grass, and quack grass, constitute the meadow weeds, this practice is not advisable, as harrowing merely breaks the rootstocks of these pests, and growth is invigorated.

Bare summer fallow is sometimes practiced for cleaning old weed fields. When this method is followed, the land should be plowed in the early summer and disked or harrowed often enough during the summer to induce germination of the weed seeds and to kill all the plants that come up. The same end can be accomplished in most cases by planting the land to a cultivated crop, in which case clean culture is required.

Cultivation to be efficient in weed eradication must be thorough and must be kept up late enough to prevent the maturing of all seeds before frost.

Smothering. The growing of a heavy, dense cover of some crop such as buckwheat, cowpeas, or soybeans that will outgrow the weeds and deprive them of light, water, and plant nutrients is another method of destroying persistent weeds. This is perhaps the best method of destroying Bermuda grass. This plant is very persistent in cultivated fields, but it may be smothered out by keeping the land well covered with dense-growing crops for 2 or more years.

Mowing. When properly handled, mowing is an important means of weed control. Mowing must be done before the seed pods are formed, as many weed plants have the ability to mature seed even after being cut.

Pasturing. Certain types of weeds may be controlled temporarily, and in some cases permanently, by pasturing with sheep, goats, or hogs. Hogs will feed on underground rootstocks of Johnson grass. Goats and sheep have been used effectively for controlling common weeds in pastures. However, many weeds are not palatable to stock and therefore would not be controlled by pasturing.

Chemical and Flame Treatments. Chemical herbicides are now used quite extensively in fighting weeds. Most of these materials are limited in usefulness on account of their cost or danger of application.

Some of them, such as carbolic and sulfuric acids, are unpleasant to handle, as they cause painful burns when they come in contact with the body; others, such as corrosive sublimate and arsenite of soda, are deadly poisons and cannot be used where livestock have access to the treated field.

Common salt is one of the cheapest and safest of herbicides but is not the most useful, since where used in large enough quantities to kill certain weeds it permeates the soil to such an extent that all growth is checked for a season. If this material is used, it should be applied in the late summer so that the harmful effect will have time to disappear, partially at least, before the following spring.

Kerosene, carbolic acid, and caustic soda are well suited to destroying small areas of persistent weeds. However, these materials completely sterilize the soil for a time and cannot be used for killing weeds in growing crops.

Iron sulfate and copper sulfate are well-known herbicides for use as weed killers in growing crops. Grains and grasses are very resistant to injury from these materials, whereas some of the common grain weeds are easily killed by them. Of these two materials, iron sulfate is probably better for general use as it is cheaper and somewhat more effective on older weeds.

Sodium chlorate is another herbicide. Grau[6] studied the chemical control of weeds in various sections of the United States and obtained satisfactory control of crab grass, plantain, field sorrel, chickweed, milk purslane, ground ivy, heal-all, and speedwell with sodium chlorate. Dandelion and goose grass were discouraged, but wild garlic was little affected. Murphy[7] secured very good control of both mowed and unmowed Bermuda grass by using two applications each of either sodium chlorate or calcium chlorate at the rate of 200 pounds per acre, 1½ months apart, from July 15 to Sept. 3. However, he points out that the rate and cost of either chemical are such that they could be recommended only for small areas.

A new type of herbicide, 2,4-D (chemically called 2,4-dichlorophen-

oxyacetic acid), causes plants to starve to death. It checks the growth of leaves and prevents the formation of new ones, and its effects travel in both directions from the place where it is applied. The effect of 2,4-D develops gradually, usually requiring from 1 to 3 weeks before the sprayed plants die and rot away. Mitchell[8] considers it one of the most successful

FIG. 30. A plot of lawn at the Plant Industry Station, Beltsville, Maryland, thickly spotted with buckhorn plantain and dandelion before being treated with 2,4-D. Compare with Fig. 31. (*Photograph by W. J. Mead.*)

weed killers. Plantain, dandelion, and other weeds can be killed when strengths of 2,4-D are used that will not injure grass. However, if the concentration of 2,4-D is sufficient to kill grasses that occur as weeds, such as quack grass and crab grass, desirable grasses will also be injured.

The use of 2,4-D in pre-emergence control of weeds is being given serious consideration by agricultural authorities. Anderson and Wolf,[9] in New Jersey, found that "2.7 pounds of 2,4-D per acre effectively controls weeds and does not have any detrimental effect on corn production." The corn was planted on May 31, and the 2,4-D was applied to the land 2 days before the corn seedlings appeared. Heavier applications of 2,4-D, although entirely killing the weeds, damaged the corn

plants. Wolf[10] concluded from later results that 1.5 pounds of 2,4-D per acre is a sufficiently heavy application.

Ammonium sulfamate, used as a spray or dry application, is a non-selective weed-killing material. It is especially recommended for use in destroying hard-to-kill woody perennials, such as poison ivy and brush growth. It does not have a prolonged sterilizing effect on the soil.

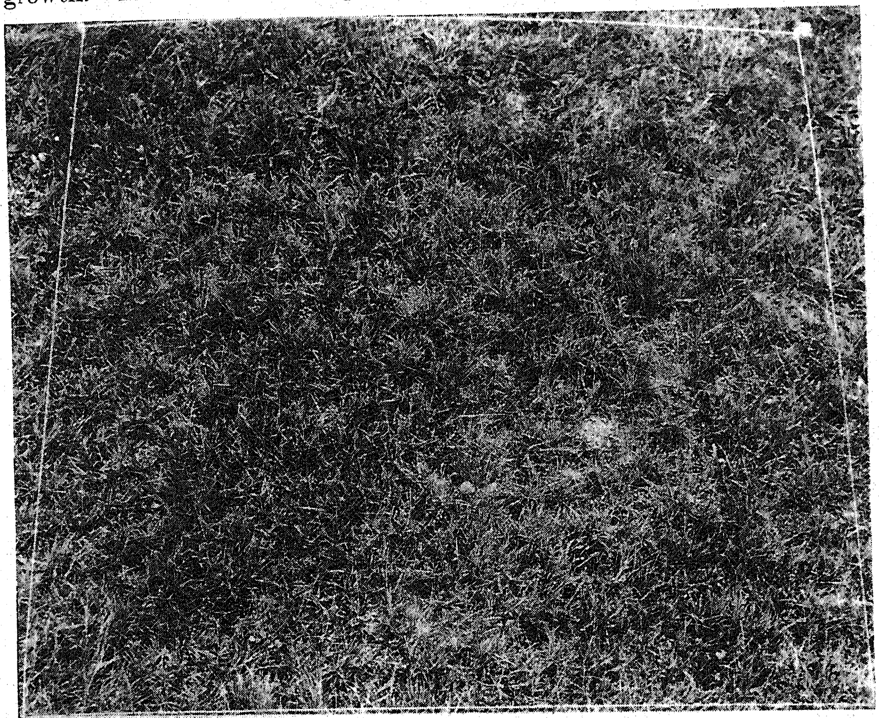

FIG. 31. The same plot of lawn, as shown in Fig. 30, 6 weeks after treatment with the herbicide 2,4-D. Practically all the weeds are killed and are scarcely visible. (*Photograph by W. J. Mead.*)

The use of flame throwers is growing in popularity in the control of weeds in intertilled crops and elsewhere. Neely and Brain[11] report results secured from control of weeds in cotton by flaming. This practice appears to have possibilities, particularly late in the season.

Crop Rotation. With each crop appear certain typical weeds that are much less serious in other crops. Pigweed, lamb's-quarter, cocklebur, and foxtail commonly occur in cornfields. Ragweed, wild mustard, cockle, wild onion, and thistles may abound in fields of small grain. Oxeye daisy, plantain, sheep sorrel, and wild carrot may occur in hay-fields. These weeds increase rapidly if a crop is grown continuously but frequently can be subdued by a change of crops.

Clean Seeds. The question of clean seeds is a very important one in weed control. Nearly all our bad weeds have been introduced in seeds of various crops, especially in grass and clover seeds. Constant vigilance should be maintained, and no seeds should be sown without careful examination for weed seeds. Those who purchase seeds for sowing should familiarize themselves with all the more noxious weed seeds and should refuse to purchase any seeds among which they are included.

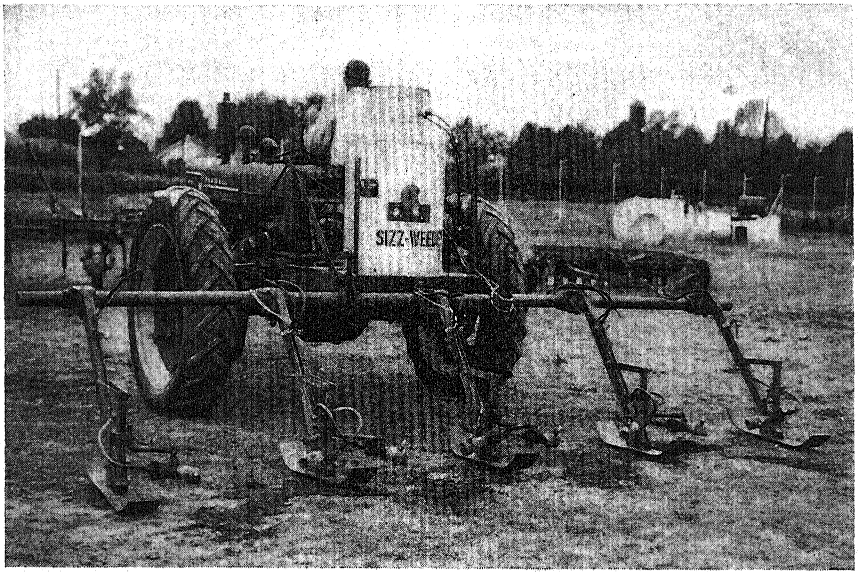

FIG. 32. Four-row flame weeder that uses bottled gas for fuel. As the machine is pulled along the crop rows, the burners—much like a plumber's blow torch—sear the young weeds in the rows with killing flame. The cotton plants have tougher stems so are unharmed. (*U.S. Dept. Agr. photograph by Forsythe.*)

The percentage of purity on the tag does not necessarily tell the desirability of the seed. Seed with a purity of 99.9 per cent should be avoided if the other 0.1 per cent was a noxious weed such as Canada thistle. This could mean a seeding of 2,400 such seed per acre.

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Topics for Discussion

1. What is a weed?

2. If it were possible, would it be desirable to destroy completely all so-called "weeds" in the United States?

3. What is the most common source of farm weed seeds?

4. Do weeds ever become a serious menace on fertile, well-worked farms?

5. Will the use of 2,4-D make weed control less costly and more practical?

CHAPTER XVIII

CROP ROTATION

Crop rotation may be defined as a more or less, regular recurrent succession of different crops on the same land. It differs from a haphazard change of crops from time to time, in that it contemplates the growing of a group of crops in regular succession through a considerable period of years according to a definite plan. Rotations may be of any length, but, owing to the limited number of crops usually profitable in a given section, they are most commonly of 3 to 7 years' duration.

Reasons for Crop Rotations. There are many benefits, both direct and indirect, to be obtained from a good rotation. Crop rotation (1) helps to control weeds, insects, and diseases; (2) may aid in maintaining the supply of organic matter in the soil; (3) may aid in the maintenance of the soil nitrogen supply; (4) often saves labor; (5) keeps the land occupied a greater part of the time with crops; (6) allows for crop alternation; (7) regulates the use of plant nutrients from the soil; (8) systematizes farming; and (9) increases crop yields.

Control of Pests. With each crop appear certain typical weeds that are much less serious in other crops. For example, pigweed, lamb's-quarter, cocklebur, and foxtail are typical weeds of cornfields. With small grains, ragweed, wild mustard, cockle, wild onion, and thistles may abound. Common weeds that occur in hayfields are oxeye daisy, plantain, sheep sorrel, and wild carrot. These weeds increase rapidly if a crop is grown continuously but can frequently be subdued by a change of crops. Many insects trouble only one plant or one group of plants. The Hessian fly, for example, does little damage except in wheat fields, and, if the wheat crop is grown continuously, the Hessian fly may increase rapidly. Changing crops is an effective method of checking the damage from insects. Sometimes it is necessary to omit the crop entirely for a few years, but usually a rotation of proper length will bring these pests within the limits of economic control.

Similarly, there are many diseases that injure one crop but are not harmful to other crops. Potato scab may become serious if the potato crop is grown on the land year after year, and smuts of grain may increase rapidly under continuous cropping to grain plants. Nearly all the plant diseases are checked to some extent and many of them are controlled by a proper rotation.

Maintenance of Organic Matter. If lands are kept constantly in tilled crops, the supply of organic matter is seriously decreased. Small-grain crops bring the same results but less rapidly. Grasses and clovers usually increase the supply of organic matter.

Uhland[1] reports that land in Missouri cropped to a good rotation for 60 years lost 30 per cent of its original supply of organic matter, but without rotation the loss averaged 69 per cent, or 2.3 times as much.

Nitrogen Supply. Clovers and legumes generally may not only increase the supply of organic matter but also help to maintain the nitrogen supply of the soil. No single cropping system will ordinarily maintain the nitrogen supply of the soil unless leguminous cover crops are alternated with the other crops.

Uhland[1] gives data from the Ohio Agricultural Experiment Station showing that land cropped to corn continuously for 15 years contained at the end of the period 1,425 pounds of nitrogen per acre, and that cropped to a rotation of corn, oats, and alfalfa 3 years contained 2,487 pounds, or 75 per cent more. In addition, the crops in the rotation produced five times as much digestible protein as the corn grown under continuous cropping.

Economy of Labor. Crop rotation often makes it possible to grow two or more crops with one soil preparation or after one plowing. Thus, in some sections where a rotation of corn, wheat, clover, and grass is practiced, the land is plowed for corn, the corn stubble is disked for wheat, and the grass and clover are seeded in the wheat without further preparation. If corn were grown continuously in these sections, the land would have to be plowed and prepared four times in the same period. The saving of labor and time made possible by the elimination of plowing and other preparation increases the area one man can handle and reduces the cost of producing an acre of crops.

Protection of the Soil. It was once believed necessary to leave land idle for a part of the time in order to maintain productivity. Now it is known that a proper rotation of crops with due attention to essential plant nutrients will bring the same results much more economically. The land represents the farmer's bank account, and all parts of it should return yearly interest. In sections where the rainfall is heavy and where climatic conditions make plant nutrients available, much loss will occur through leaching unless growing plants are present to take up these soluble materials, and much loss will occur from soil erosion unless the land is kept covered with erosion-resistant crops. It follows that some system of cropping that will keep the ground covered will conserve more plant nutrients than is possible where the soil lies bare a portion of the year.

Uhland[1] reports that land cropped to corn continuously for 10 years in Missouri lost 27.2 per cent of the rainfall as runoff, and, on the average, 50.9 tons of soil per acre, equivalent to over ⅓ inch. Adjacent land cropped to a 3-year rotation of corn, wheat, and hay lost only 16.5 per cent of the rainfall as runoff and lost only 7.51 tons of soil per acre annually. During the 9-year period 1934–1942, in Ohio, the runoff from land in a 4-year rotation was only one-half that of land cropped to corn every year, and the soil loss was only one-seventh as great. In Iowa, during the 10-year period 1933–1942, Uhland[1] reports that land that grew corn each year lost 2.3 times as much of the rainfall, and 5.32 times as much of the soil as land in a 3-year rotation of corn, oats, and clover. On land in alfalfa and bluegrass, the runoff was low, and there was only a trace of soil loss.

Alternation of Crops. Rotation may provide for the alternation of deep- and shallow-rooted crops and thus allow for a more complete use of the soil. Potatoes, tobacco, and small grains are shallow-rooted crops. If such crops are used exclusively, only the surface soil is utilized. On the other hand corn, clover, and alfalfa are deep-rooted crops, and, where alternated with the first-mentioned group, utilize the soil more completely.

Balanced Removal of Plant Nutrients from the Soil Allowed. Plants use nutrients from the soil in different proportions, and when properly alternated they may reduce the different nutrient materials of the soil in a more desirable proportion. If, however, a single crop that feeds heavily on one group of materials is used continuously, this group may be greatly reduced, while another group of materials that might be used in large proportions by other crops is used only sparingly.

The beneficial effects of sods turned under for corn crops are generally attributed to the influence of the nitrogen supply, but Albrecht[2] suggests that the important factor may be the accumulated moisture in the subsoil. He reports results of Missouri experiments, conducted over a 14-year period, which showed that land growing grass crops absorbed 87.4 per cent of the rainfall; a 3-year rotation with one sod crop, 85.5 per cent; and continuous corn, only 69.6 per cent. The difference amounted to an equivalent of increased rainfall of 7.2 inches for grass, and 6.4 inches for the rotation as compared with continuous corn. Alternation of crops is desirable in order that all available nutrients may be used by crops and loss from leaching may thus be reduced.

However, it should be remembered that the larger crop yields obtained from rotations result in a greater total removal of plant nutrients than is the case when single crops are grown. Therefore, rotation alone is not sufficient to maintain productivity.

Farming Systematized. Crop rotation allows a more complete year's work with few periods of idleness, and by distributing the risks among several crops helps to prevent complete failure. Usually a cropping system simplifies the farm layout and reduces the number of fields on the farm. It also enables one to estimate ahead of time the amount of labor, the quantity of seed, and the power and machinery necessary for the operation of the farm and does away with extreme rush work that is so common when haphazard cropping is practiced.

Increase of Crop Yields. Rotation of crops usually increases crop yields. However, if yields were not increased, rotation of crops would be desirable as a means of reducing the cost of production.

Leighty[3] reports the results of an experiment covering a period of 30 years, conducted at the Missouri Agricultural Experiment Station. The average yields of corn, oats, and wheat grown in a 4-year rotation were: corn, 39 bushels per acre; oats, 28 bushels; and wheat, 24 bushels. These crops when grown continuously on the same land yielded: corn, 21 bushels per acre; oats, 17 bushels; and wheat, 10 bushels.

Kipps and Hutcheson[4] found in Virginia that corn from the same land for 24 years yielded 16.82 bushels per acre when no manure or fertilizer was used, and 32.72 bushels when manure and fertilizer were applied. In a rotation of corn, wheat, and hay 2 years during the same 24-year period, the yield of corn that was not manured or fertilized was 32.51 bushels per acre, whereas corn that was manured and fertilized yielded 56.23 bushels.

In the case of wheat, fertilizer was of far more importance than rotation.[4] The average yield of wheat under continuous cropping was 19.49 bushels per acre when the land was manured and fertilized and 8.69 bushels when not manured and fertilized, whereas on rotated land the average yield was 21.22 bushels when manured and fertilized and 6.60 bushels with no treatment.

The average yield of hay where fertilizer and manure were used was 1.70 tons per acre under continuous cropping, and 2.12 tons when reseeded every 2 years.[4] Where fertilizer and manure were not used, the yields of hay were 0.98 ton under continuous cropping and 1.14 tons when reseeded every 2 years. Hay grown in rotation with corn and wheat yielded less than under continuous cropping.

DeTurk and others,[5] in reporting yield records from the Morrow plots in Illinois, which had been in operation 52 years, concluded that crop rotation has noticeably improved the yields over continuous corn growing. The 3-year rotation of corn, oats, and clover has been more effective than a 2-year rotation of corn and oats in maintaining yields over the entire period. Since the addition of sweet clover as a green-manuring crop

to the 2-year rotation of corn and oats, during the past 12 years, the yield of corn on the 2-year rotation has been greater than that on the 3-year rotation. They found that, in all cases where the land was untreated, yields declined, but the decline was more pronounced under continuous cropping to corn.

Essentials of a Good Rotation. The characteristics of a good cropping system, according to Warren,[6] are as follows:

1. The area of each crop should be nearly the same year after year unless there is a definite reason for changing it.
2. The rotation should provide roughage and pasture for the animals kept.
3. The rotation should include one tilled crop for the elimination of weeds.
4. It is desirable that a rotation include a sod.
5. The rotation and feeding system should provide for keeping up the organic matter of the soil.
6. The rotation should provide as large an area of the most profitable cash crop or crops as can be cared for.

Planning the Rotation. After the characteristics of a good cropping rotation have been determined, the next problem is to select the best adapted crops. A crop should be grown not just because it will pay, but because it will pay best in the particular type of farming followed.

The proper sequence of crops is also an important consideration. In general, the most profitable crop should be given the best place in the rotation. Attention should also be given to the labor requirements as influenced by the sequence. In sections where grain and grass are grown, a cultivated crop is usually followed by a small-grain crop, and this in turn is followed by grasses and clovers. Such a sequence minimizes the labor of soil preparation and at the same time brings each crop where it is likely to do best in the rotation. The kind of soil has an important influence on the kind of crops to grow in a rotation, and, when there are two types of soil on the same farm, it may be advisable to have two rotations. In the bright-tobacco sections of the South it is usually advisable to have one rotation for tobacco and another for the production of food and feed. This practice is best because it is practically impossible to produce bright tobacco of high quality on soils that have been built up to a high state of productivity by the use of legumes and from the use of farmyard manure.

Duration of Rotations. The duration of a rotation is governed somewhat by the type of farming. In trucking sections, where the most salable products are usually cultivated crops, the rotations are commonly of short duration. Where hay is the chief cash crop, longer rotations

are practiced, and in such sections 6- or 7-year rotations are not uncommon. Probably the most common rotations of the United States are of 3 or 4 years' duration.

Examples of Good Rotations. Leighty[3] states, "Each principal type of farming region in the United States has one leading crop around which rotations and livestock production (if any livestock production system can be used to advantage) are built up." A desirable rotation is one that will give the greatest net return over a period of years. Probably the most widely recommended rotation consists of (1) a tilled crop, (2) a small grain, and (3) a legume or grass crop, in the order named, according to Enlow.[7]

Since corn is the most valuable crop grown in the Corn Belt, crop rotations are centered around corn in that region. Leighty[3] reports that an Indiana study shows that, of the rotations, 30 per cent consists of corn, wheat, and clover; 27 per cent of corn, oats, and clover; 14 per cent of corn, corn, oats, and clover; and 9 per cent of corn, soybeans, wheat, and clover. In Iowa, 46 per cent consists of corn and oats; 24 per cent of corn, corn, corn, and oats; and 5 per cent of corn, corn, oats, and clover.

In the Cotton Belt, cotton is the principal crop, and rotations should be centered around it. Where one-half the land is to be planted in cotton, a suggested rotation is first year, cotton, followed in part by a winter legume; second year, cotton; third year, summer legumes for hay or seed followed by winter legumes; and fourth year, corn, interplanted with summer legumes.

In the dairy region, especially in the Lake states, a suggested rotation is first year, corn, mostly for silage; second year, oats; and third year, clover.

In the main wheat regions, crop rotations are not so common as in many other sections of the country. Wheat is the money crop. Leighty[3] reports that in some sections of Kansas, 62 per cent of the crop land was planted to wheat, and 6 per cent to oats and barley, 18 per cent to corn, 4 per cent to sorghum, and 6 per cent to hay, mostly alfalfa. In some other sections wheat occupied 80 to 87 per cent of the cropland.

In the Red River Valley, one-third of the cropland was seeded to wheat, 27 per cent to the other small grains or flax, 4 per cent was in cultivated crops—corn or potatoes, 15 per cent was in hay or sweet clover pasture, and 15 per cent was either fallow or in crops to be plowed under for soil improvement.

In the dry-land areas of the Great Plains and the Intermountain Region, wheat, either winter or spring, is the main cash crop, except where the soils are unsuitable for its production and in limited areas where a cash crop of greater value is adapted. The proportion of wheat

in the farming scheme may vary from practically 100 per cent to a place subordinate to feed crops. Summer fallow enters into dry-farming rotations in most sections, particularly in the drier areas.

Difficulties and Limitations of Crop Rotations. Rotations are not always advisable. There may be special conditions, such as extremely high prices, which may make it advisable to grow only one crop for a long period. In case of silage corn, which is very heavy and bulky, it may be desirable to grow it on a field near the barn each year, manure and commercial fertilizers being used to keep the soil in proper condition. Weather conditions or other accidents may interfere with the rotation. Soils may be suited for only one or two crops. In trucking sections the prospective demand for a certain crop may make it advisable to substitute that crop for some other crop and thus break the rotation. However, in most cases it will be found advisable to establish a rotation made up of crops well adapted to the section and adhere to it through periods of high and low prices.

Effects of Continuous Cropping. Under ordinary conditions continuous cropping lowers the productivity of the soil. This result may be due to one or more of several factors. (1) The constant removal of crops without the addition of organic material exhausts the soil humus, and as a result the mechanical condition of the soil becomes poor. (2) If the mineral elements are not returned to the soil, one or more of them may be reduced to such an extent that profitable crops can no longer be produced. (3) If no legumes are grown, nitrogen may become the limiting factor in crop production. (4) The bases may be used up or leached out of the soil; thus it may become acid and unfit for the production of many crops. (5) Erosion may carry away considerable plant nutrients from the soil. However, productivity may be maintained if the soils are properly handled. Examples may be seen in all the older agricultural sections of our country. Although the Shenandoah Valley of Virginia is one of the oldest agricultural sections of the country, the soils are apparently not decreasing in productivity. In the Piedmont section of Virginia, lands that have been cropped constantly ever since the earliest settlement of the country are still productive, and many of them under proper handling seem to be improving in productivity.

The proper rotation of crops in itself cannot maintain soil productivity, but it is one of the chief essentials in keeping up crop yields.

Strip Cropping. The program of strip cropping, sponsored by the Soil Conservation Service, helps to make rotations more effective and practical. In strip farming, large fields and long slopes can be protected against erosion by plowing alternate strips, always leaving protection strips of erosion-resistant crops between the clean-tilled strips. In this

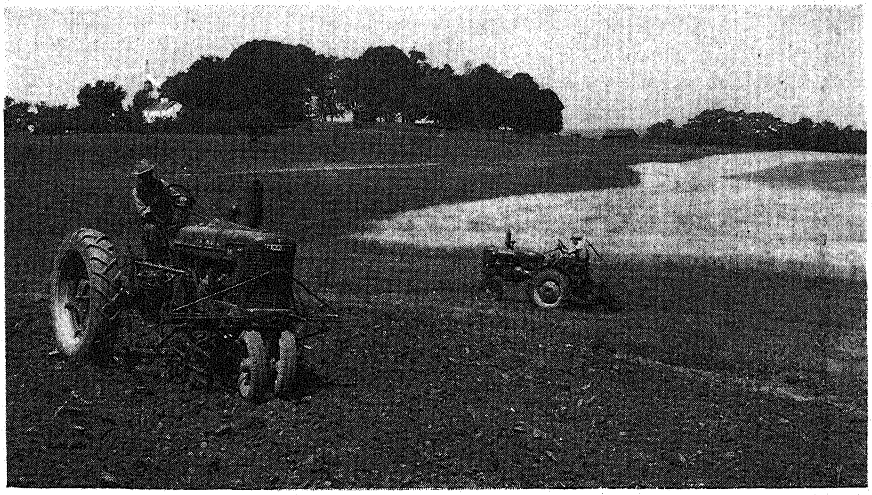

FIG. 33. Contour strip cropping in a field in Virginia. Soil and plant nutrients are being conserved. (*U.S. Dept. Agr., Soil Conservation Service.*)

FIG. 34. Contour strip cropping is being practiced on this farm.

way rainfall runoff and soil and plant food losses are reduced, and a better balance of soil-building and harvested crops is encouraged by the use of proper crop rotations made possible through a greater number of small fields being provided.

Kell[8] states:

Strip cropping with rows on the contour not only conserves soil and water but also time and energy. Less time is required to cultivate a given area in long rows than in short rows because of the fewer turns, and contour rows can usually be made longer than rows in the square fenced field. Often two or more fields can be thrown together, thus making longer rows and sometimes saving fence. In tractor operations on the contour, time is saved by not having to stop to change

gears in going up and down hill. By keeping the strips and rows on the level, less power is required, an important item on some farms.

Reducing the runoff by strip cropping prevents the loss of plant food applied in the form of fertilizer, manure, or crop residue and is thus reflected in crop yields.

Enlow[6] calls attention to a still further advantage of strip farming: ease of harvesting small grains with binder or combine without destroying any of the grain, since the first round can be made on the grass strips.

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Topics for Discussion

1. Can rotations in themselves improve lands?

2. Is soil maintenance a major or a minor reason for crop rotation?

3. What are the most important considerations in making up rotations for a section?

4. How may the topography of a section affect the duration of rotation?

SECTION II

CEREAL OR GRAIN CROPS

CHAPTER XIX

CORN (Zea mays)

Corn is preeminently the grain crop of the United States. It is grown in nearly every part of the country but reaches its greatest prominence in

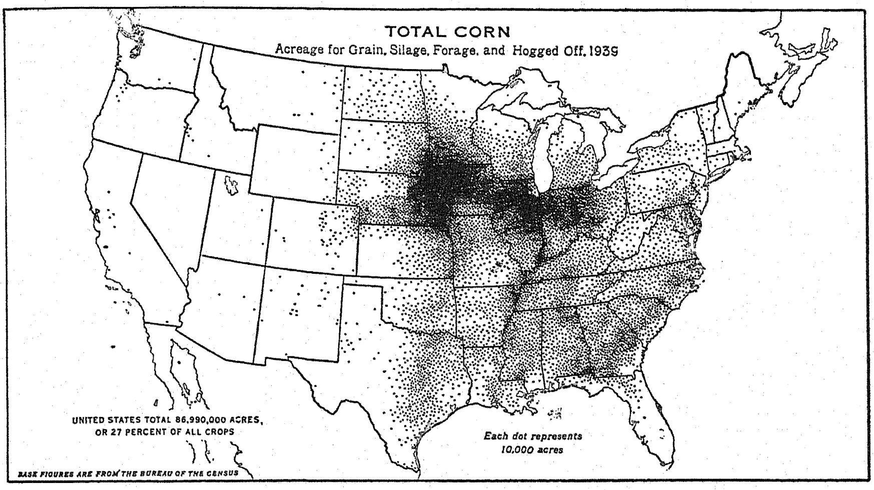

FIG. 35. The corn crop of the United States makes up over one-half of the world's annual production. Acreage devoted to corn is about one-sixth of the total land area available for crop production in the United States. Planting of corn begins in the heart of the Corn Belt about May 1, and the average growing season is from 150 to 180 days. Corn is not usually grown where the mean summer temperature is less than 66°F. or where the average night temperature during the growing season is lower than 55°. Profitable corn production requires a fertile, well-drained loam soil, well supplied with humus that can be worked easily with modern farm machinery. Iowa has the largest acreage of corn, with 9,331,000 acres; Illinois is second with 7,786,000 acres; and Nebraska, third with 6,305,000 acres. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

the Corn Belt of the Middle West. The value of the corn crop exceeds that of any other crop grown in this country. The average annual farm value of the corn crop from 1941 to 1945 inclusive, was $3,043,950,800.

World Production. The United States ranks first in corn production. Argentina, producing about three-fourths as much as the state of Iowa,

ranks second. The average yield of corn per acre for the 5-year period 1935–1939, was, for the United States, 25.0 bushels; for Argentina, 28.0 bushels; for Italy, 31.3 bushels; for Austria, 40.0 bushels; for Hungary, 31.5 bushels; and for France, 26.9 bushels.[1]

Production in the United States. The average annual yield for the United States as a whole, for the 5-year period 1935–1939 was 2,315,539,000 bushels. In each of the five years, 1942 to 1946, the production was over 3 billion bushels with the average acre yield over 30 bushels. During the 10-year period 1933–1942, Iowa produced an annual average corn yield of 421,769,000 bushels; Illionois, 330,989,000 bushels; Indiana, 164,777,000 bushels; Minnesota, 155,934,000 bushels; and Ohio, 147,230,000 bushels. During this period, these five states produced 51.5 per cent of the entire crop of corn in this country.[1]

Historical. Corn was probably first cultivated in the high plateau region of central or southern Mexico. The cultivation of corn probably started in this region about the beginning of the Christian Era. It spread rapidly both northward and southward, reaching the Rio Grande about 700 A.D. and Maine about 1000 A.D.

Corn was found under cultivation when Columbus discovered America, and soon after the discovery of the New World it was introduced into the Eastern Hemisphere. The culture of corn has spread rapidly, and it is a very important crop in the United States as well as in other countries. Leighty, Warburton, Stine, and Baker[2] state that the Virginia colonists planted 30 or 40 acres in 1609, and about 500 acres in 1614. In 1631, according to these authorities, there was a surplus of corn to export. The yield of corn in the United States increased from 377,531,857 bushels in 1839 to 3,287,927,000 bushels in 1946.

Corn does not exist in the wild state. It is probably closely related to gama grass and teosinte. Gama grass has a tassel resembling that of corn, whereas teosinte bears a branched ear. Teosinte crosses readily with corn and to some extent with gama grass. It is probable that corn and gama grass do not cross.

Groups of Corn Varieties. Corn may be classified into six principal types or groups: pod corn, popcorn, flint corn, dent corn, soft corn, and sweet corn. The classification is based largely on the character of the kernels.

Pod Corn (*Zea mays tunicata*). In this group each kernel is enclosed in a pod or husk, and the ear formed is also enclosed in husks. The plants are frequently very leafy, and the tassels are often heavy and inclined to bear kernels. Pod corn is sometimes known as cow corn, forage corn, husk corn, and primitive corn.

Popcorn (*Zea mays everta*). This group is characterized by a very hard, corneous endosperm and small kernels. The ability to pop is due to the explosion of moisture upon the application of heat. There are two main types of popcorn: rice, with pointed kernels, and pearl, with rounded kernels. The kernels vary greatly in color and size.

Flint Corn (*Zea mays indurata*). The endosperm is soft and starchy in the center and completely enclosed by a very hard outer layer. The kernels are usually rounded but are sometimes short and flat. The flint corns are early maturing and for this reason are suited for growing in cool climates and on high altitudes where dent corns will not mature. The kernels are of various colors.

Dent Corn (*Zea mays indentata*). In the case of dent corn there are both hard and soft starches. The hard starch extends on the sides, and the soft starch is in the center and extends to the top of the kernels. In the drying and shrinking of the soft starch, various forms and degrees of indentation result. This group is the most widely cultivated group of corn, and it is by far the most common one in the Corn Belt. The plants vary in height from 6 to 18 feet; the ear, in length from 6 to 12 or 14 inches; and the rows on the ears, from 8 to 24.

Soft Corn (*Zea mays amylacea*). The kernels of soft corn are composed entirely of soft starch. All colors exist, but white and blue are most common, and the kernels are shaped like flint kernels. This group is also known as "flour corn" and as "squaw corn."

Sweet Corn (*Zea mays saccharata*). The kernels of sweet corn are translucent, horny, and more or less wrinkled in appearance. It has a sweeter taste than other corns, as the endosperm contains sugar as well as starch.

There are many other types of corns but they are of comparatively little importance, with the possible exception of *waxy* corn, which, now appears, can be used to replace tapioca starch and in the manufacture of adhesives.

Varieties. The choice of the variety or varieties of corn to grow will depend upon soil, climate, and the use to which the crop is to be put. The conditions vary to so great an extent over comparatively limited areas that recommendations as to varieties can be only general. Selection of the variety to use should be based largely upon the results secured by the nearest experiment station and upon the practice of the best farmers of the community.

Yellow Corn Compared with White Corn. It has been the opinion of many farmers for a long time that yellow corn is superior in feeding value to white corn. Various chemical analyses did not show any marked, consistent differences in the composition of these two kinds of corn. However, in recent years it has been shown that yellow corn is superior

to white as a source of Vitamin A. Feeding experiments show yellow corn to be superior to white corn for feeding hogs and other classes of livestock. The difference has been attributed to the difference in the content of Vitamin A.

Uses. Of the 91,202,000 acres of corn harvested in 1945 in the United States, 80,812,000 acres were harvested for grain, 4,641,000 acres were harvested for silage, and 5,749,000 acres were used for hogging

FIG. 36. Weeds being controlled in corn with 2,4-D. The two rows of corn on the right were not treated but were cultivated to eliminate weeds, but weeds still persisted. The two rows on the left were treated with 1½ pounds of 2,4-D per acre at time of planting. These two treated rows were not cultivated. (*Wolf, D. E., and J. C. Anderson. N.J. Agr. Expt. Sta.* 1947.)

down, grazing, or forage. Thus it may be noted that the corn crop is grown primarily for grain.

In 1944 the grain crop was used as follows: Breakfast foods, 12,000,000 bushels; farm household use, 20,757,000 bushels; corn meal, grits, etc., 62,000,000 bushels; wet-process products (starch, sirup, sugar, etc.), 124,589,000 bushels; alcohol and distilled spirits, 36,986,000 bushels; seed, 12,935,000 bushels; feed, other uses, and waste (mostly feed), 2,830,298,000 bushels; exports, 16,611,000 bushels; and stocks at end of year, 307,831,000 bushels.

Of the total grain crop better than 85 per cent was fed to animals. Of the corn used for seed and fed, about 85 per cent was used on the farms

where produced. Only about one-fifth of the corn crop is sold as grain. Hogs consume more corn than all the other farm animals combined.

Cornstalks are being used to some extent for the purpose of making paper, wallboard, and similar materials. Corncobs are being used to some degree in industry, as for making furfural needed in producing synthetic rubber (Lathrop[3]).

Among the by-products of corn processing are germ meal, gluten feed and meal, and distillery residues.

HYBRID CORN

In recent years, all other methods of corn breeding have been practically superseded by a system that involves inbreeding by self-fertilization until homozygosity is approached and pure lines are obtained, after which the more desirable lines are combined and reinvigorated by cross-fertilization. Close inbreeding for several generations enables the breeder to eliminate lines that carry undesirable characteristics and to recombine the characteristics of desirable lines by cross-fertilization. Many characteristics are isolated from corn by inbreeding. Of these may be mentioned variation in color, leaf characteristics, root development, tassel growth, stalk growth, and disease susceptibility. Also there have been isolated inbred strains with variations in protein, fat, starch content, and susceptibility to insect injury. It has been shown that by the recombination of the proper inbred strains, seed adapted to the local requirements of any section may be produced.

Inbreeding in corn results in a reduction in size, vigor, and productiveness, but when two inbred strains are crossed, the seeds so obtained may produce plants far more vigorous than the parent variety and superior to it in yield, uniformity, disease resistance, and many other characteristics. The outward appearance of any inbred strain gives little indication of its ability to produce a desirable combination when crossed with other inbred strains. Therefore it is necessary to make trial crosses of the isolated strains obtained by inbreeding until superior combinations are discovered.

Inbred Strains. The superiority of crosses made from inbred strains is not indefinitely maintained, and it is necessary to produce seed stocks from the original inbred strains each year if optimum results from the system of breeding are to be obtained. In starting to produce inbred lines, a large number of selected ears from a chosen variety are planted in separate rows in the field. When the plants are ready to silk, a number of plants from each row are self-pollinated by hand. The ear shoots are, of course, carefully covered to prevent cross-pollination. An inbred strain starting from an ear is called a self-fertilized line. From each self-fertilized line two or more ears are selected for planting the next year and

the system is followed for three or four generations. At this time, many of the lines are fairly well fixed in type and are inferior in vigor.

Kinds of Hybrids. To obtain best results, it is necessary to test all the best inbred strains in combinations with one another. When a good combination of two inbred strains, called a "single cross," is found, it is a simple matter to produce crossed corn by planting the strains in alternate rows and detasseling one of them before any pollen is shed. If all tassels are carefully removed from one strain before any pollen is shed, all seeds produced on this row are necessarily crossed. By maintaining two crossing plats, in separate fields, detasseling one type in one field and the other type in the second field, it is not difficult to produce inbred seed of both types each year.

The principal difficulty in producing single crosses is the low yield and poor quality of the seed obtained from inbred strains. This difficulty may be overcome by crossing two first-generation hybrids, making what are known as "double crosses." Thus, strains *A* and *B* may be brought together in single cross *AB*, and strains *C* and *D* brought together in single cross *CD*. When *AB* and *CD* are crossed, double cross *ABCD* is produced. The two single crosses, being vigorous, produce good yields of high-quality seed, and the double crosses so produced are often more productive than either parent.

In addition to single crosses involving two inbred lines and double crosses involving four inbred lines, there are top crosses and three-way crosses. The *top cross* is produced when an inbred line is crossed with an open-pollinated variety. A *three-way cross* is produced when an inbred line is crossed with a single-cross hybrid. The main advantage of these crosses is that it is easier to find one inbred for a top cross or three inbreds for a three-way cross that combine well than it is to find four for a double cross. Most of the hybrids used commercially are double crosses. A diagrammatic method of producing single- and double-cross hybrids is shown in Fig. 37.

In producing double-cross hybrids commercially, the two single crosses are planted in an isolated field. Frequently, four rows are planted of the cross to be used as the female parent and two rows of the cross to be used as the male parent, with the plantings repeated across the field. The tassels are removed from the female rows as they appear and before any pollen is shed. The seed produced by the female plants is double-crossed hybrid seed and is sold as commercial corn hybrid seed.

The same procedure is followed in producing single-cross hybrids from two inbreds.

Hybrid Seed Loses Yielding Ability. Some farmers are inclined to save seed from double-cross hybrids for planting. This practice is

undesirable as crops produced from such seed tend to revert to inbred lines. The reduction in yield depends upon the kind of cross, productivity of the inbreds, and the vigor of the single crosses.

Characteristics of Good Hybrids. In the United States there has been a rapid increase in use of hybrid corn because of its superiority over

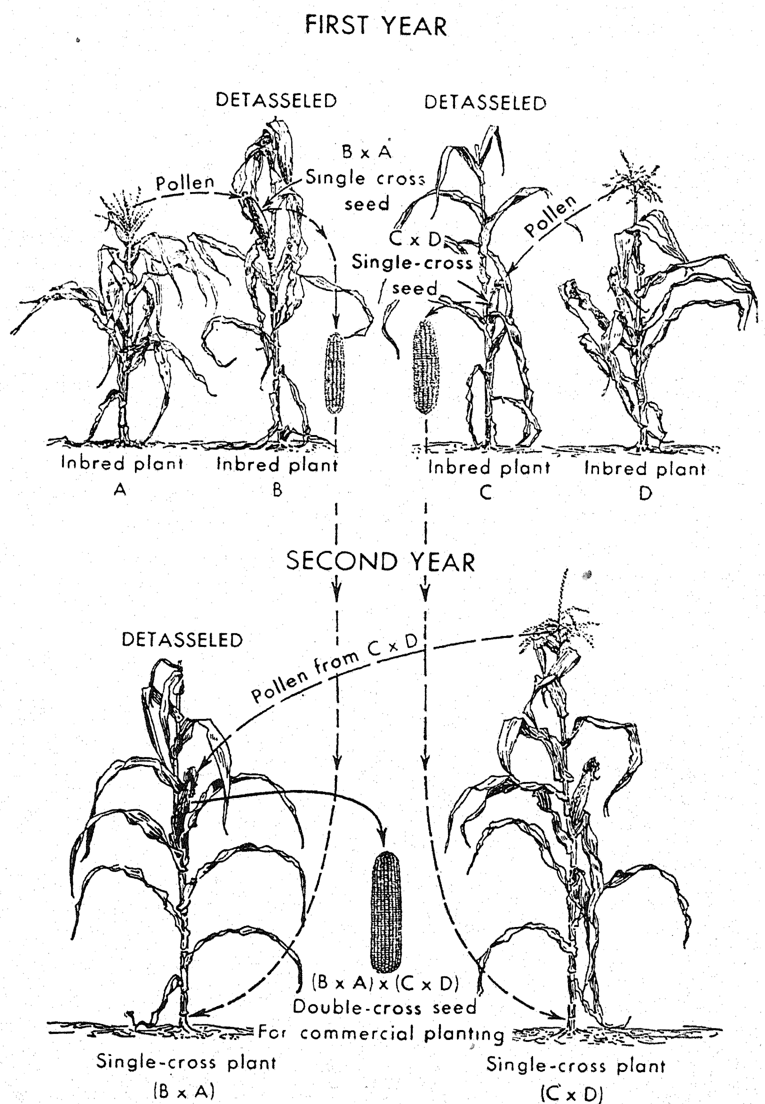

Fig. 37. Diagram of method of crossing inbred plants and the resulting single crosses to produce double-cross hybrid seed. (*U.S. Dept. Agr. Farmers' Bul.* 1744.[4])

open-pollinated varieties. This increase, however, has been brought about in a comparatively short time.

In 1933, only 0.1 per cent of the corn acreage was planted with hybrids; in 1938, 14.9 per cent; in 1940, 30.4 per cent; in 1942, 45.7 per cent; in 1944, 58.0 per cent; in 1946, 68.7 per cent; and in 1947, 71.4 per cent. During 1947, more than 90 per cent of the corn acreage in the Corn Belt states was planted with corn hybrids.

FIG. 38. Field of hybrid corn in Illinois being produced for seed. The male parent is not detasseled. The female parent is being detasseled by girls standing on the platform of the detasseling machine as it moves through the field.

Not all hybrids are good, and no one hybrid is best in all areas. Therefore, care must be used in selecting the right hybrid for the conditions under which it is to be grown.

The desirable characteristics of hybrids, according to Dungan and others[5] are

1. Higher yield than the best adapted open-pollinated varieties.
2. Stiff stalks that remain erect until harvest.
3. Strong root systems that prevent the plants from lodging during the growing season.
4. Resistance to insects, such as chinch bugs, grasshoppers, southern corn rootworm, corn-ear worm.
5. Resistance to rots of roots, stalks, and ears.
6. Early maturity to enable plants to escape damage from killing

frosts in the fall, and yet late enough to occupy the growing season fully.

7. High quality of grain for feeding and marketing.

8. Resistance to injury from early low temperatures in the fall, so as to reach maturity in the period of favorable weather that often follows.

9. Capacity to use soil minerals, nitrogen, and moisture effectively.

10. Resistance to extremes of heat and drought in summer.

FIG. 39. Double-crossed hybrid seed corn is being produced in this field. The seed will be gathered from the detasseled rows. The tasseled rows furnish the pollen. In this view, there is one male row to three female rows.

11. Capacity to perform well in competition with other corn plants when planted thickly.

12. Ability to mature the ear before the stalk and leaves mature.

In discussing the production of corn hybrids and its future, Jenkins[6] stated in 1936, "There is every reason to believe that greater progress will be made in corn improvement in the next 25 or 30 years than has been made since the crop came into possession of the white man nearly 450 years ago."

CULTURE

Seed. The importance of selection of seed corn for type and maturity has been shown by many experiments, when open-pollinated varieties were used. The careful selection of seed corn is of special consideration in those sections where the growing season is short and corn is not likely to become fully developed. The earlier strains of corn should be selected and stored in such a way as to become dry before freezing.

Seed corn may be selected from the crib, at husking time, or in the field from the standing stalks. Field selection is best, since at this time the early-maturing ears can be secured, the conditions of growth, such as soil and stand, can be studied, the characteristics of the plant and the location of the ear can be observed, and the ears can be carefully dried and stored.

With the increasing use of hybrid seed corn, many of the considerations involved in the selection of seed when open-pollinated varieties are used are eliminated.

Germination Test. When there is reason to believe that the seed corn will not germinate satisfactorily when planted, a germination test should be made for each ear. In this test usually six or more kernels are removed from each ear at different places, and the viability determined.

Time of Planting. This will vary with the section of the country, as would be expected. Planting begins before Feb. 1 in the extreme southern portions of Texas and at progressively later dates toward the north. The advance northward is at the rate of about 13 miles per day until May 1, when during the next 10 days planting begins throughout the Northern states. In the Corn Belt, the planting season is at its height about May 15 and ends about June 1. In the South a second or late planting may be made. In any section the planting season usually extends over at least 2 weeks.

Dungan[7] found that when corn was planted in early May, late May, and early June the intermediate date proved best, from the standpoint of yield, for short-season varieties in northern Illinois, but that early planting proved best for full-season varieties in both northern and central Illinois. Quality of grain, as measured by bushel weight and percentage of moisture, for shelled corn, was reduced by delayed planting in all cases. Kiesselbach and others,[8] in Nebraska, reporting on the results secured over a period of 12 years, state: "There was a tendency in most years for either the early- or late-planted corn to yield the highest, but, on the average, corn planted on intermediate dates yielded practically the same."

Depth of Planting. Corn seeds should be planted deep enough to ensure plenty of moisture for germination. The depth will, therefore, vary to some extent on different soils and under different climatic conditions. On heavy soils the seeds should be planted more shallow than on soils of open structure, such as those of a sandy nature. Corn is usually planted from 1 to 4 inches deep, but the results secured in Ohio, Indiana, and Illinois do not show any increase in yield for planting deeper than 2 inches.

Rate of Planting and Spacing. The rate of planting will vary with the soil, climate, and variety of corn.

In the South, on the poorer soils, corn is often grown two stalks to the hill 4 or 5 feet apart each way. Farther north the stalks vary in number from two to four per hill in hills about 3½ feet apart each way.

Richey[9] states that corn may be planted about 50 per cent thicker on land producing 80 bushels of corn per acre than on land producing 40 bushels. Kiesselbach and others[8] state that an average stand of 2½ to 3 plants in hills 3½ feet apart, or its equivalent in drilled rows, is considered the most practical rate of planting in eastern Nebraska.

The general practice in growing hybrid corn is to plant about one-fourth thicker than was customary with the open-pollinated varieties.

Bryan and others,[10] in Iowa, planted corn in 21- by 21-inch spacing compared with 42- by 42-inch, with 14,224 plants per acre in both cases. They found no significant differences in yield, but there were more lodged plants in the closer spacings. Dungan[11] in Illinois, in a 7-year comparison of single-plant hills with multiple-plant hills, with the same number of plants per acre, found the yield to be greater from the single-plant hills on productive soils when the rainfall was well distributed and plentiful. The increase in the yield was the result of increase in both size and number of ears per stalk. Dungan concludes that "It would seem that, on the more productive soils, the present tendency on the part of farmers to narrow rows and to drill the corn is a move in the right direction for maximum yields."

Many Iowa and other Middle Western farmers are not growing enough corn plants per acre to get the best yields from their fertilizer, according to Nelson and Dumenil,[12] agronomists at the Iowa Agricultural Experiment Station.

Reporting results of 2 years' tests, they state:

> If both moisture and fertility are high, it appears that greatest yields will come from stands with four or five stalks per hill, or 15,000 to 19,000 stalks per acre. Adding an extra stalk per 40- by 40-inch hill on well-fertilized soil boosted yields 8 to 16 bushels per acre, where heavier than normal applications of fertilizer were made. And, on some of Iowa's fertile soils, better yields can be obtained with thicker stands even when fertilizer is not used.

Methods of Planting. Corn may be "surface planted," *i.e.*, the land is prepared level, and as a general rule the seed are planted from 1 to 3 inches deep. On the wetter lands of the South, ridges are thrown up and made level on top and the corn planted as on unridged land. Corn may also be planted in furrows. This method is used only where the soils have an open structure and where the rainfall is low and is known as "listing."

Corn may be drilled in rows or planted in check rows; in the latter

method, the corn may be cultivated both ways. The seeds may be planted by hand or with machinery. On the market are a number of one-row and two-row planters drawn by one and two horses, respectively, as well as two- and four-row planters drawn by tractors.

Cultivation. The subject of cultivation of the corn crop has been discussed in Chap. XII. The recommendations vary to a considerable extent, according to the section of the country in which the crop is grown.

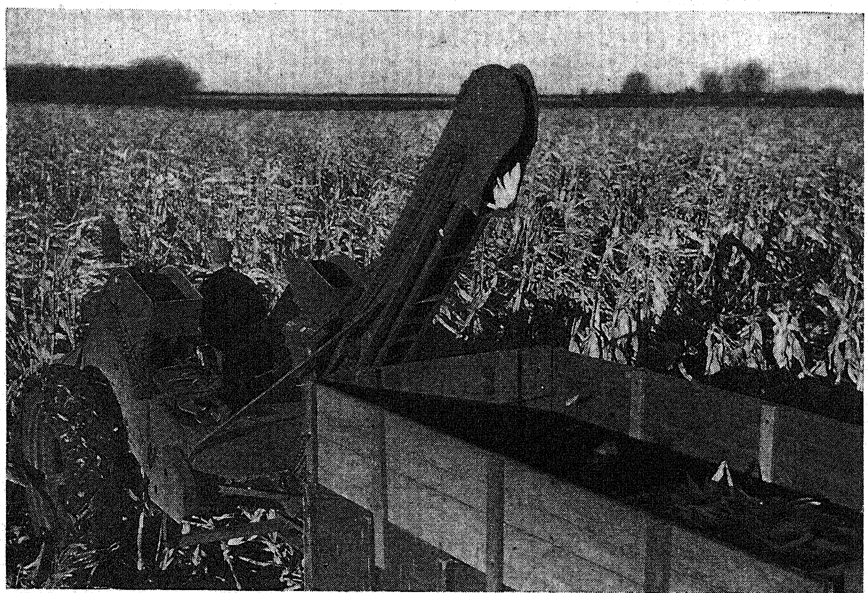

FIG. 40. Moving through a Sangamon County, Illinois, field, the mechanical corn picker picks the ears from two rows of standing corn and drops them into the field wagon hitched on behind. (*U.S. Dept. Agr. photograph by Knell.*)

The outstanding consideration in the cultivation of corn is the killing of weeds.

The modern one- and two-row riding cultivators show a marked advance over the old "single-shovel" and "double-shovel" one-horse cultivators. There are several types of riding cultivators on the market that allow a rather wide selection of implements for various conditions, and of increasing popularity are the tractor cultivators.

Harvesting. The harvesting of the corn crop and the comparison of the various methods are given and discussed in Chap. XIII. The method of harvesting varies widely in the different sections of the country.

Silage. The subject of silage has been discussed in Chap. XV. However, the production of corn for silage differs but little from the production of the crop for grain. The crop is cut somewhat earlier for

silage than for grain, there being a difference of about 1 week, if best results are to be expected. Silage corn is usually planted somewhat more thickly than when the crop is to be used for grain. However, if the rate of planting is increased too much, the quality of the silage is lowered, because of the lower ratio of grain to stalk in the thicker plantings. After a certain thickness of planting is reached, the yield of grain begins to decrease, although the stover continues to increase. Corn is usually drilled when grown for silage.

SOME INSECT PESTS

European Corn Borer. The European corn borer (*Pyransta nutralis*) was imported into the United States and Canada in broomcorn from Hungary or Italy between 1909 and 1914.

The European corn borer in the adult stage is a moth. In the New England area there are two generations, and in the Middle West and Canada there is only one. In the latter sections the adults are present in the fields during late June, throughout July, and during early August. The eggs are laid in masses, principally upon the underside of corn leaves, and hatch in from 4 to 9 days. The newly hatched borer, or larva, is about 1/16 inch long, with a black head and a pale yellow body, bearing several rows of small black or brown spots. It feeds for several days on the surface of the leaf near where it was hatched and then enters the plant. It usually completes its growth by the middle of August, when it is about 1 inch long and 1/8 inch thick. The head is dark brown or black, and the upper surface of the body ranges in color from light brown to dark brown and to pink. Each division of the body has a row of small dark-brown spots, and several narrow dark-brown or pink lines extend lengthwise of the body. The underside of the body is flesh color and has no markings.

The insect passes the winter in the form of a borer, or "worm," within infested plants. In late May or early June it changes to the resting, or pupa, stage in which it remains for 10 days or 2 weeks, after which it emerges as a moth.

In New England the overwintering borers enter the resting stage in late April or in May. The moths appear in June, the eggs are laid, and the borers become fully grown from the middle of July to early August, when they enter a short resting stage. The moths emerge from this second-brood resting stage during August and early September. The eggs laid by these second-brood moths hatch and develop as described for the first brood. The borer becomes full grown before cold weather and overwinters within the corn and many other kinds of plants.

The corn borer injures principally the corn plant, but many other

kinds of plants are infested, especially in the New England area. The damages so far have reached large proportions. Where several borers are present in one corn plant, injury results from the interference in the passage of nutrients, and the plants become weakened and often break over. The most noticeable signs of corn-borer injury are tassels that have broken over with sawdustlike material at the breaks. The borer enters practically all parts of the plants except the fibrous roots. The point where the corn borer is at work is indicated by small holes in the plant with accumulations of sawdustlike material at or below the holes.

Control. In the control of the pest a cleanup program is followed. The policy is to destroy all cornstalks, cobs, and refuse before May 1 each year by plowing under completely, and burning or feeding the crops to livestock, direct from the field, as silage or as finely cut or shredded material. In harvesting the corn the stubble should be cut low. In New England it is more difficult to effect a thorough cleanup than it is in the Middle West and Canada, as the borer infests a large variety of plants in the former area. Fall plowing is more effective in New England than in the other areas.

Late-planted corn (after June 10) usually escapes severe damage from the borer. This practice may be followed when the pest is numerous.

Where a thorough cleanup program has been carried out, the losses from the corn borer have been small. However, the cost of production is greater under such conditions than under the ordinary method of producing corn.

Corn Root Aphid. The corn root aphid (*Aphis maidiradicis*) causes serious injury to corn east of the Rocky Mountains and especially in the Corn Belt, where corn is grown continuously on the same land. The aphid is a small soft-bodied insect about the size of a pinhead, spherical in shape, bluish green in color, and covered with a fine whitish powder that gives the grayish-green appearance. There are four forms of the aphid. The males and the egg-laying females occur only in the fall. The eggs laid by the females are taken by ants to their nests and kept during the winter. In the spring and through the summer winged and wingless females are produced, and these give birth to living young. Through tunnels made by the ants the aphids that hatch from the eggs are carried by ants to the roots of corn plants. These aphids mature in about 15 days and give birth to a second generation. This and the succeeding generation give birth to living young. About 16 generations are produced from spring to fall. The males and egg-laying females begin to appear about the first of October, and the eggs are laid and stored by the ants. The ants in return for their activities and attention to the aphids secure a sweetish fluid that is produced by the aphids.

The aphids cluster on the roots of plants, preferably the corn plant, and suck the juice of the plants. The effect on the plant is similar to that of drought, and the most noticeable injury occurs while the plants are yet small. The infested plants become dwarfed and the leaves brown and discolored. The plants are seldom killed outright, and injury from attacks to the older plants may pass unnoticed. Anthills are to be found at or near the corn hills affected by the aphids.

Control. Crop rotation and good cultural methods are very effective in reducing the injury of the aphids. Deep plowing in the late fall and winter and harrowing early in the spring will aid in destroying the anthills that harbor the eggs of the aphids.

Chinch Bug. The chinch bug (*Blissus leucopterus*) attacks such crops as corn, wheat, oats, sorghum, and millet. It is especially destructive east of the Rocky Mountains and from Manitoba to Texas. The adult is about $\frac{1}{5}$ inch long and occurs in two forms, one with short wings and the other with long wings. Both forms are white just after emergence from the pupal stage but soon turn black. The upper wings are whitish at the base and white at the tips and contain a black spot near the center. The underwings are whitish.

The adults appear in the spring and lay their eggs in the soil about the roots and on the roots and stems of wheat, especially on the lower leaves. During the summer the eggs may be found in connection with corn and the succulent crops. The eggs hatch in 2 to 3 weeks. The nymphs produced often do serious injury to small grains and grasses upon which they become full grown about harvest. When wheat is harvested, they migrate to oats and corn, and the migration takes place on foot, although the adults have wings. Eggs are laid upon the unfolding corn leaves, and the nymphs begin to emerge in about 10 days. The second brood matures on corn in August and September, and it is this generation that goes through the winter. The adults hibernate over the winter in bunches of grass, in shocks of corn, in corn stubble, or under any available rubbish or material along fence rows, ditch banks, etc.

Control. In the control of the chinch bug, it is usually necessary to combat it throughout the entire season. The periods of special importance in combating the insects are in November and early December, when they have just gone into winter quarters; from the appearance in the spring until wheat harvest; and from the time the corn and sorghum crops are harvested until the adults begin to hibernate.

The places of hibernation should be destroyed by burning or plowing under. The migration of the insects to corn or from one field to another can be checked by use of a dust furrow as a barrier. A furrow should be plowed around the threatened field on the sides from which the attack is likely to come and the soil thoroughly pulverized by repeatedly dragging

a heavy log in the furrow. The dust will largely prevent the insect from crawling over the steep side of the furrow, which should be next to the threatened crop. Moreover, if holes are made in the furrow at intervals, the insects will accumulate in these holes and may be killed. The furrow may also be made with a groove drag.

The dust furrow is effective only in dry weather or in dry sections of the country. In humid areas a strip of coal tar may be run around the field. The land may be prepared for the tar by plowing and rolling and by placing the tar strip on the rolled surface. At times it may be advisable to spray the crops to kill the insects on the plants.

SOME DISEASES

No part of the corn plant appears immune to disease attacks. The losses may be reduced through proper selection and treatment of the seed, use of resistant varieties and hybrids, and proper rotations and fertilizations.

Root, Stalk, and Ear Rots. The root, stalk, and ear rot diseases of corn are caused by several fungi. *Fusarium*, which also causes the scab disease of wheat, is one of the common causes of the disease. *Diplodia* and *Giberella* fungi are others. The infection occurs chiefly in the roots, the base of the stalk, and the ears, but the symptoms may appear in all parts of the plant. The presence of the disease in the field may be indicated by some or all of the following symptoms, which are grouped for convenience into four stages in the development of the plants.

In the *seedling stage* the presence of the disease may reveal itself by death of the plants, by seedling blight accompanied by infection of roots and lower part of stalks, or by yellowing and stunting of seedlings that do not succumb at once. In the *young-plant stage*, when the corn is about knee-high, the presence of the disease is shown by irregularity in the height of plants, by dead tissue at tips of leaves, by discoloration and rotting of the base of the stalk, rotting of roots, and by wilting of diseased plants on hot, dry days. In the *silk* and *tassel stage* the diseased plants develop tassels and silks about 5 to 10 days later than normal plants, and this development is accompanied by the death of the tassels and tops, by firing of the lower leaves, and by leaning of stalks due to the weakened condition of the roots. The symptoms of diseased plants in the *ear stage* are premature death or unduly delayed ripening. The late-maturing stalks may be barren or bear ears varying in size and quality from nubbins to those of full size. Frequently the diseased plants are either leaning or blown down. The disease in the ear stage may be also shown by shank infection. Frequently, the shanks of ears on diseased plants are broken or rotten, and the ears hang down. The ears

borne by such shanks may be rotten or soggy, or they may ripen but have kernels that are rough, shrunken, starchy, or dull in color. The butts of the ears are often shredded and discolored.

When the ears are affected by the Diplodia fungus (*Diplodia zeae*), a dense white mold appears between the rows of kernels. The fusarium fungus (*Fusarium moniliforme*) causes a pink rot that may affect a part or all of the kernels. The Giberella ear rot, caused by the fungus *Giberella zeae*, is a pink infection that normally starts at the tip of the ear and moves downward toward the butt. Diplodia also causes a dry rot of susceptible corn plants, attacking both stalk and roots, with resulting lodging near harvesttime and reduction in yield.

Control. Infection may come from two sources—the seed and the soil. The soil infection is very important where the land is cropped continuously to corn but relatively unimportant when corn is grown only once in a 3- or 4-year rotation. If disease-free seeds are used, the infection from the soil can be reduced by practicing crop rotation and by building up the productivity of the soil.

Field selection will aid greatly in obtaining disease-free seeds. The best ears are those which ripen early on good, normal, upright stalks that are still green when the husks turn yellow to brown and the ears become firm. The ears should not be borne perfectly erect nor should they hang straight down. The shank should be unbroken and the kernels free from rot. In the dent varieties the kernels should have rather shallow, smooth dents and bright color. The ears should be inspected before making the germination test. Ears on which the shank attachment is discolored or cracked and shredded or those whose kernels are dull in appearance should be discarded. Kernels that are very starchy and have deep, rough dents are undesirable. In the germination test, kernels that show any rotting of the roots or of the inside of the grain should be discarded.

Koehler and Holbert[13] report that the injurious effects of root, stalk, and ear rot diseases may be reduced when the diseased seed is dried quickly after harvest to 14 per cent moisture and treated with mercury compounds, using 1½ ounces to treat a bushel of seed. Each kernel should be thoroughly covered with the dust used. These compounds are poisonous, and the dust should not be inhaled nor the treated seed fed to livestock.

There are now corn hybrids resistant to some of these diseases, and their use is recommended when they are otherwise adapted.

Smut. Smut (*Ustilago zeae*), a fungous disease of corn, causes smut masses to form that may be seen on any part of the corn plant—roots, stalks, leaves, ears, and tassels. The smut masses are at first covered

with white membranes that later rupture and expose the black, sooty spores. These spores carry the fungus over winter and produce secondary spores that infect the succeeding crop.

Infection may take place at any time during the growth of the plant. Any young growing tissue of the corn plant from the seedling stage on to near maturity may become infected. As a rule smut does not appear until the plants are about a foot high, and it is most prevalent when the ears are forming. Moisture is necessary for infection, and for this reason the disease is often worse in wet seasons. The spores may have remained in the soil from the previous corn crop, or they may have been applied in the manure that was made from feeding diseased corn ears or plants.

Control. No specific or easily applied control methods are known, as in the case of the wheat smuts. Infection may be reduced by rotation of crops and avoidance of infested manure. Strains of corn resistant to smut have been developed. The practice of ensiling corn reduces the amount of smut in subsequent crops, as the spores cannot survive the fermentation process in the silo. It does not appear that the smut masses are poisonous to cattle, since large quantities have been fed to animals without any ill effects.

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Topics for Discussion

1. Why is the Mississippi Valley the most important corn section of the world?

2. Why do the highest authentic acre yields of corn yet reported occur in the Southeastern states rather than in the Corn Belt?

3. Does the fact that culture of corn is responsible for a large proportion of the soil erosion that has taken place in the United States necessarily imply that our corn acreage should be reduced?

4. Compare corn with the other important crops of your area as to total digestible nutrients produced and the amount of plant food removed from the soil per acre.

5. In view of the great improvement made in corn through hybridization, is there much opportunity for further development?

CHAPTER XX

WHEAT (Triticum sativum)

Of the cereals, wheat ranks next to corn in importance in the United States. Of the crops, however, it ranks fourth in value of all crops grown (9.9 per cent), and third in acreage (16.9 per cent).[1]

Wheat is important for the following reasons: (1) Many farmers grow it, (2) a large acreage of land is annually devoted to it, (3) it constitutes

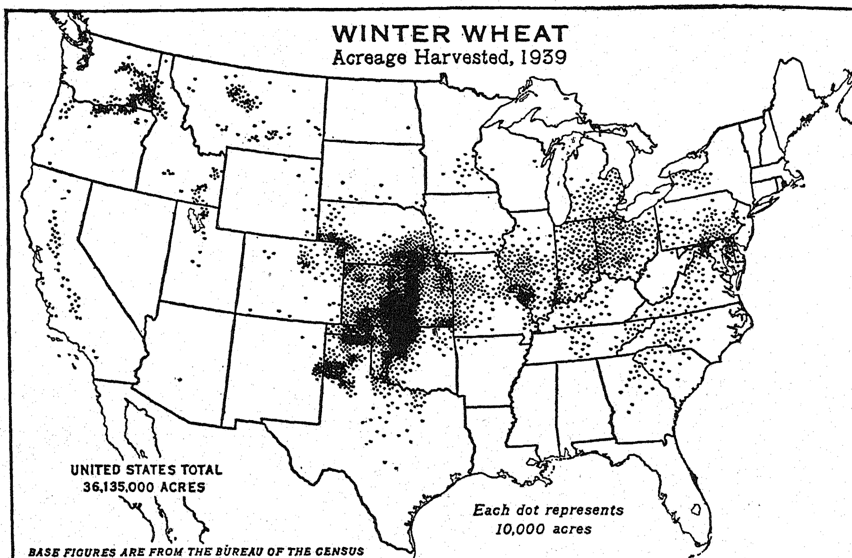

FIG. 41. The winter wheat acreage in 1939 was about 71.5 per cent of the total acreage of wheat in the United States and consisted of hard red winter, and white classes. The hard red winter region lies principally in the South Central states, and the soft red winter region in the Eastern states. The white wheats are grown chiefly in the Far Western states. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

an important part of our domestic commerce, (4) it contributes a large part of the exports of the nation, (5) it fits in well with most rotations, and (6) it is the national bread crop.

During the 5-year period 1941–1945,[2] an average of 496.6 million bushels of wheat were consumed as food in the United States. This amount was represented as 159.4 pounds per capita consumption as flour and 3.7 pounds as cereal.

Between 1929 and 1939,[1] about 63.4 per cent of the crop was used for

food, 16.3 per cent for feed, 11.2 per cent for seed, and the remainder for exports or inventory.

World Production. Comparable data on world production are unsatisfactory since none are available from the Union of Soviet Socialist Republics since 1934. Therefore by using the data during the 5-year period 1930–1934,[2] we find that the U.S.S.R. produced an average of 860,448,000 bushels of wheat, with an average acre yield of 10.0 bushels; China, 820,624,000 bushels, with an average acre yield of 16.7 bushels; United States, 732,527,000 bushels, with an average acre yield of 13.5 bushels; India, 355,593,000 bushels, with an average acre yield of 10.7 bushels; and Canada 348,560,000 bushels, with an average acre yield of 13.6 bushels.

The data for 1945, which does not include the U.S.S.R. and China, show that wheat production in the United States was 1,123,143,000 bushels (average yield 17.3 bushels); India, 390,432,000 bushels (average yield 10.9 bushels); Canada, 305,912,000 bushels (average yield 13.1 bushels).

Production in the United States. During the 12-year period 1934–1945,[2] Kansas produced an average of 147,712,000 bushels of wheat; Oklahoma, 53,432,000 bushels; and Nebraska, 45,592,000 bushels. These three states produced approximately 40 per cent of the winter wheat crop.

During the same period (1934–1945),[2] North Dakota produced an average of 72,233,000 bushels; Montana, 31,464,000 bushels; and South Dakota, 21,146,000 bushels. These three states produced approximately 66 per cent of the spring wheat crop.

At the same time (1934–1945),[2] North Dakota produced an average of 25,025,000 bushels; South Dakota, 3,973,000 bushels; and Minnesota, 1,023,000 bushels. These three states produced approximately 100 per cent of the durum wheat crop.

During this 12-year period, the average acre yield of the three main types of wheat in the United States was as follows: winter, 13.3 bushels; durum, 11.7 bushels; and spring, 9.5 bushels.

Historical. The origin of wheat is not known, as the cultivation of the crop is older than the history of man. The finding of wheat in certain monuments shows it was cultivated before the Hebrew Scriptures were written. Wheat is first mentioned in the Bible in Genesis, Chapter 30, verse 14. The lake dwellers of Switzerland cultivated wheat in the Stone Age. Chinese history shows that wheat was grown 2700 B.C., and it was one of the five kinds of seeds sown in their annual ceremony. The many names for wheat given in the ancient languages indicate that the existence of the crop dates back to remote times.

The geographical origin of wheat is in doubt. It is thought by some that common wheat originated in southwestern Asia. According to DeCandolle, wheat once grew wild in the Euphrates and Tigris valleys and from there spread to the remainder of the world.

Wheat was not grown in America until after the discovery of the New World by Columbus, but production started on the Atlantic Coast in the Virginia Colony at least as early as 1618. The production moved westward with the settlement of the country. In 1839 the wheat crop of the United States amounted to 84,823,272 bushels. At this time New York, Pennsylvania, Virginia, and Ohio produced 60 per cent of the crop.

In the next 20 years wheat production moved rapidly westward. In 1939 the total production for the country was 741,180,000 bushels.

Classification. According to Clark, Martin, and Ball,[3] after Hackel, there are in cultivation eight groups or types of wheat. They are as follows:

- *Triticum*
  - *sativum*
    - *tenax*
      - *vulgare* Vill., Common wheat
        - Hard red spring
        - Hard red winter
        - Soft red winter
        - White
      - *compactum* Host., Club wheat
      - *turgidum* L., Poulard wheat
      - *durum* Desf., Durum wheat
    - *dicoccum* Schr., Emmer
    - *spelta* L., Spelt
  - *polonicum* L., Polish wheat
  - *monococcum* L., Einkorn

These wheat types vary in importance in their production in the United States. They may be considered under two headings—important and unimportant types.

Important Wheat Types. The most important wheat types in this country are common, durum, and club.

Common. Common wheat is extensively grown in this country, comprising about 95 per cent of the entire wheat crop. The spikelets usually contain two or three kernels, but sometimes four or more. They vary in color from white to dark red. They fall from the chaff in threshing. The head is broad in the plane of the rows of spikelets, narrow on the sides between the rows, and usually tapers toward the apex. The stems are generally hollow but sometimes may be slightly pithy.

There are a number of both winter and spring varieties grown, including both bearded and beardless forms. Common wheat may be subdivided into hard red winter, hard red spring, soft red winter, and white.

Hard red winter wheats are the most important commercial class of wheat. They are grown extensively in the central sections of the Great

Plains area, particularly in Kansas and Nebraska. The grain is hard and generally high in protein content. In quality, as a bread wheat, it ranks second only to hard spring wheat. In 1939, 47.6 per cent of the wheat acreage in this country was grown with this class.

Hard red spring wheat is grown, in general, where winters are too severe for winter wheat and in the subhumid areas of the Pacific North-

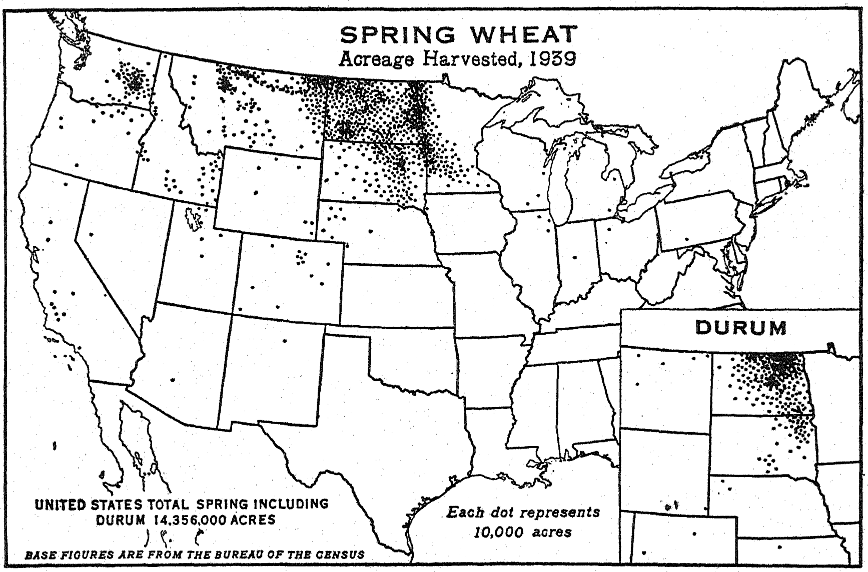

FIG. 42. Acreage of spring wheat represents about twenty-five per cent of the total wheat acreage. The two general spring wheat areas are in the North Central states where the winters are severe (and where the fall-sown winter wheat does not generally survive) and in the subhumid areas of the Pacific Northwest states. The durum wheats are grown almost wholly in the North Central states where in 1939 the estimated area was 3,372,000. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

west states. The bulk of the crop is grown in the two Dakotas, Montana, and Washington. The annual rainfall in this area varies from 15 to 25 inches. This class of wheat is noted for its high protein content and excellent breadmaking characteristics. It is used extensively for blends with weaker wheats throughout the world. In 1939, 20.9 per cent of the wheat acreage in this country was grown with this class of wheat.

Soft red winter wheat is grown mostly under humid conditions. In this region there is usually ample but not excessive rainfall. The winters are moderately cool but not severe, except in the northern part, where the ground is usually covered with snow during the coldest part of the year. Because of the relatively high rainfall, above 30 inches, most of the wheat of this region has soft grain of low protein content, which

produces a flour most satisfactory for pastries, such as cakes, cookies, and pies. The bulk of the soft winter wheat is produced in Ohio, Illinois, Indiana, Missouri, and Michigan. In 1939, 19.6 per cent of the wheat acreage in this country was grown with soft red winter wheat.

White wheat is grown chiefly in the Far West, but to some extent in the Great Lakes region. In the West, Washington, California, Oregon, and Idaho lead in production; in the East, New York and Michigan lead in production. White wheats are mainly used for pastry purposes, but some of them go into shredded wheat and bread. In 1939, 6.6 per cent of the wheat acreage grown was white.

Durum. Durum wheat is grown in the hard red spring wheat area. It is resistant to drought and black stem rust. The center of production is generally moving westward to drier districts. The greatest production of durum wheat is in North and South Dakota and Minnesota. The crop is used largely for making macaroni, spaghetti, vermicelli, and other edible pastes. The kernels of these wheats are the hardest known and for this reason are often called "hard" wheats. The spikelets contain 2 to 4 kernels. The kernels are long, very hard in fracture, sometimes translucent and vitreous, and amber to red in color. They fall from the chaff in threshing. Practically all the varieties are suitable only for spring sowing. The spikes are compact, usually rather slender and always bearded. The durum wheats constituted 5.3 per cent of the entire acreage devoted to wheat in 1939.

Club. Club wheat is of minor importance in the United States, being grown only in Washington, Oregon, California, and Idaho. It is used for making starchy flours for pastry or for export to South America and to the Orient. The spikelets contain from three to five kernels. The kernels are usually short and small, occasionally round, frequently boat-shaped, often "pinched" from pressure, and white to red in color but usually white. They fall from the chaff in threshing. There are both winter and spring varieties, but more of the latter. There are both bearded and beardless varieties. The spikes are usually very short and dense and are frequently four-sided. The spikelets fit very close together and thus give a compact spike. The culms are short, stiff, and erect. These wheats are used for making crackers and starchy breakfast foods; and in some localities the flour is used for breadmaking.

Unimportant Wheat Types. In this group the wheat types other than common, durum, and club will be discussed.

Poulard wheat is not grown to any great extent in the United States. The kernels are large, proportionately short and usually boat-shaped, somewhat hard, light yellowish to red, sometimes nearly white in color, and often vitreous. The spikes are long, often four-sided, compact,

awned, and sometimes compound or branched. The culms are stiff, thick, and sometimes pithy.

Emmer has two kernels to the spikelet, one being located somewhat above the other. The kernels are hard, red, and compressed and remain in the chaff in threshing. There are winter and spring varieties, all of which are awned. Emmer seems to be hardy and will produce a fair crop under adverse conditions of soil and climate. The stems are usually pithy. The crop is used for feed in this country.

Spelt usually bears two kernels to each spikelet. The kernels are light red in color, long, and somewhat compressed, with narrow, shallow creases and acute tips. Also they are flattened on the creased surfaces and have sharp edges. Since the spike is very brittle, the rachis is broken into pieces in threshing, and the kernel is held in the chaff. Spelt may be distinguished from emmer in that the pedicel is blunt and thick, whereas in emmer it is short and pointed. Also, emmer spikelets are flattened on the inner side instead of being convex as in spelt. There are both winter and spring varieties as well as bearded and beardless types. The production is small in this country.

Polish wheat is not grown extensively in the United States. The kernels are very large, proportionally long, yellowish white in color and very hard. The spikes are very large, loosely formed, bluish-green in color before ripening, and bearded. The glumes are long, narrow, and papery in structure and stand out from the spike. Polish wheat is not suitable for breadmaking, but is adapted for use in the production of macaroni.

Einkorn, as the name implies, has one kernel to the spikelet. It is supposed to be the most primitive type of wheat. It is not cultivated in America.

Hard and Soft Wheats. As a rule the hard wheats are dark in color, whereas the soft wheats are pale. In fracture the hard wheats are dark and vitreous in structure and show no white starch. On the other hand, the soft wheats possess a white, starchy interior.

The soft wheats are lower in gluten than the hard wheats, make a "weak" flour, and are preferred for making biscuits, crackers, pies, and starchy breakfast foods. The hard wheats are higher in gluten than the soft wheats and make a "strong" flour. The hard wheats are especially desirable for breadmaking. The strength of flour depends largely upon the gluten it contains, which gives to bread its elastic quality and its ability to absorb water. Gluten may be removed from dough by washing with water. A good-quality gluten is pale yellow in color, tenacious, and elastic; gluten of poor quality is dark-colored, tenacious, but not elastic.

Varieties. It is not practicable to attempt to name the varieties best suited to all sections of the country. The variety of wheat best suited for particular conditions should be determined by trial. Such tests are being conducted by the various experiment stations of the country, in cooperation with the U.S. Department of Agriculture.

According to Bayles,[4] more than fifty improved varieties of wheat have been distributed to American farmers in the past decade. They resist rust, smut, other diseases, drought, insects, or winterkilling, major

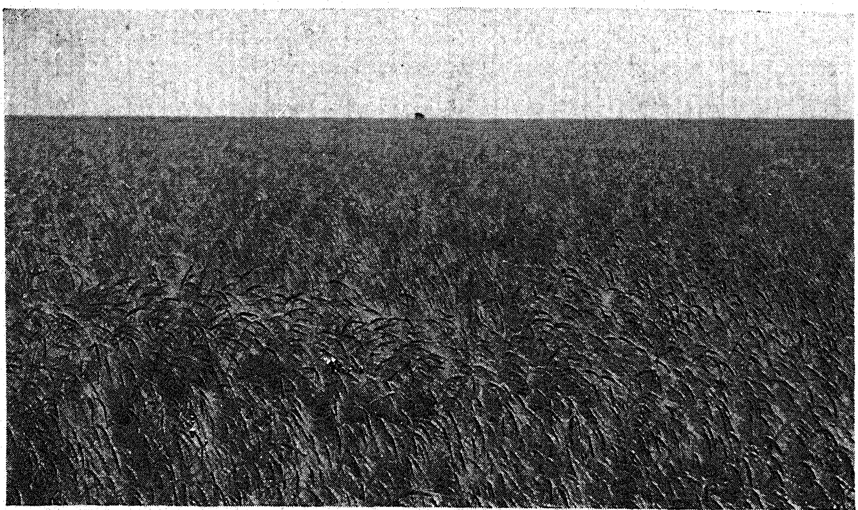

FIG. 43. Wheat field in Oldham County, Texas. (*U.S. Dept. Agr. photograph.*)

hazards that threaten crops always in one place or another. They increased our total wheat production by more than 800 million bushels in the period 1942–1946.

New hard red spring wheat varieties include Thatcher, Pilot, Rival, Regent, Mida, Newthatch, Henry, and Cadet.

In the hard red winter wheat region, Tenmarq, Cheyenne, Nebred, Pawnee, Comanche, Wichita, and Westar are newly developed varieties.

In the soft red winter wheat region, recently developed varieties include Thorne, Fairfield, Prairie, Blackhawk, Hardired, Sanford, and Austin. Of the white winter wheats, Yorkwin and Cornell 595 are leaders.

New durum varieties are Carleton and Stewart.

Uses. Most of the wheat crop produced in the United States is consumed within the country. In 1945 about 7 per cent of the wheat crop was used for seed, about 10 per cent fed to livestock, less than 1 per cent ground at mill for home use, and the remainder was sold.

The bulk of the wheat used in this country is made into flour. Among the by-products of wheat may be mentioned bran, shorts, and middlings.

CULTURE

Seed. It is of great importance to use high-yielding strains of good varieties of wheat if maximum yields are to be expected. Since wheat plants are self-fertilized, it is to be expected that they will tend to remain uniform in yielding capacity, provided they do not become mixed through

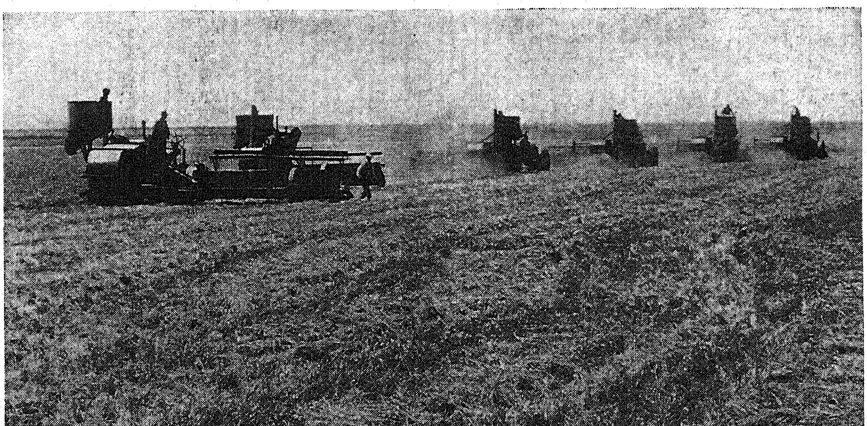

FIG. 44. Combining wheat in Deaf Smith County, Texas. (*U.S. Dept. Agr. photograph by Harmon.*)

mechanical means such as the itinerant threshing machine. If it becomes necessary to change seed wheat, the new seed selected should be of proved merit and known to be adapted to the region in which the crop is to be planted.

It is also good practice to grade wheat with the fanning mill, or seed cleaner, in order to remove the diseased and very chaffy seeds and weed seeds. Most of the results in comparing light and heavy seed, as separated by the fanning mill, show but slight difference in yield. However, as shown in Chap. VII, when the difference in size of seeds is great enough, the large seeds give higher yields than the small seeds.

Time of Seeding. The proper time of seeding wheat in the fall depends upon several conditions, especially the likelihood of winter-killing and attacks from the Hessian fly.

The optimum date of seeding winter wheat is independent of soil type, annual precipitation, and rate of seeding but is related somewhat to temperature. The highest average yields were secured from seedings ranging from Sept. 1 at Moccasin, Montana, and Archer, Wyoming, to

Oct. 15 at Amarillo, Texas. The optimum date of seeding was when the mean daily temperature was between 50 and 62°F.

Wheat should be seeded early enough to become well established before winter, but not so early that it makes a rank growth or starts to shoot before winter, nor early enough to become infested with Hessian fly if this insect is prevalent. Unless wheat is grown for pasture, there is seldom any advantage from very early seeding, and there is considerable danger from lodging, winterkilling, and the Hessian fly (Salmon and Taylor[5]). In many localities, wheat is seeded at the time of the average first frost.

Spring wheat produces best results when seeded as early as practicable in the spring. The early-seeded crop is also less subject to severe stem-rust damage.

Rate of Seeding. It is to be expected that the rate of seeding will vary under different conditions. The optimum rate of seeding wheat is practically independent of soil type, moisture, locality, date of seeding, cultural treatment, and variety.

Within fairly wide limits, it makes but little difference how much seed is planted to an acre. Four to six pecks an acre is a very common rule throughout much of the more humid wheat area. When wheat is planted later than the normal date for the locality, an increase of 1 or 2 pecks an acre in rate of seeding is considered advisable. In the drier regions, 3 or 4 pecks an acre is considered sufficient (Rather[6]).

Usually less seed is required per acre on more productive land than on less productive land.

Depth of Seeding. The depth at which wheat should be sown will vary with the conditions. The kind of soil, moisture, preparation of the seedbed, and other factors will modify the results. Wheat may be seeded deeper on a sandy soil than on a clay soil. It seems that the proper depth for seeding wheat is about 1 to 3 inches.

Broadcast Sowing Compared with Drilling. Practically all of the wheat sown in this country is drilled. The reasons usually given for drilling are that better germination and less winterkilling result. Drilled seeds are more uniformly covered with soil to the proper depth, the ridges made by the drill bring about conditions more favorable to the reduction of winter injury, and higher yields are almost always produced.

Cultivation. In sections of Europe wheat is sometimes cultivated, that is, grown in rows with the soil intertilled. There land is scarce while labor is plentiful and comparatively cheap. In the United States the cultivation of wheat is not a common practice. Here land is comparatively plentiful, but labor is scarce and high priced.

SOME INSECT PESTS

Hessian Fly. The Hessian fly (*Phytophaga destructor*), which is especially destructive to wheat, in the adult stage is a dark-colored gnat about $\frac{1}{10}$ inch long. Upon the leaves of fall-sown wheat the female lays its eggs, which hatch into maggots in a few days. These maggots burrow beneath the leaf sheaths and form the "flaxseed" stage and winter there. In the spring the fly emerges from the "flaxseed." The spring adults lay eggs upon the wheat plant, and the young maggots that hatch develop "flaxseeds." These "flaxseeds" in turn produce the fall brood.

The young plants infested with Hessian fly have broader, darker green, shorter leaves than the healthy plants. In the case of the older plants the presence of the attack may be indicated by falling of the plants and by the presence of the "flaxseeds" in the stalk.

Control. In control, all the measures recommended are preventive. Late sowing has given good results in many seasons as most of the flies appear in early fall, the date being definite for each locality. Crop rotation, plowing under the stubble soon after harvesting where practicable, destruction of volunteer wheat, good preparation of the seedbed, and proper fertilizing are advised.

Probably the most effective results to date have been achieved in the breeding of winter wheats resistant to the Hessian fly. Kawvale and Pawnee wheats have been developed and carry a considerable degree of fly resistance (Packard and others[7]).

Wheat Jointworm. The wheat jointworm (*Hermolita tritici*) in the adult stage is a small four-winged fly about $\frac{1}{8}$ inch long with the joints of the legs and feet yellow. It appears in April, May, or early June according to the latitude. Soon after emergence the adults that overwinter in the stubble lay their eggs in the wheat stems. The eggs hatch in about 14 days into larvae, remain where hatched, and live on the juices of the plant. Thus the stem is weakened, and lodging often results. The larvae reach maturity just before the wheat ripens; when the crop is harvested the majority of the larvae are left in the stubble, and in November and December they change to pupae. The insect overwinters in the pupal stage, and the adults emerge about May and fly to growing wheat.

The infested plants may not show evidence of injury by any outward appearance. However, they contain a hard, woody place in the stem usually just above the second or third node above the ground. In some plants the infestation may occur in more than one place; the points of infestation are at times shown by wartlike swellings, and there is a strong tendency for plants to lodge.

Control. The measures used in control of this pest are rotation of crops and plowing under or destruction of the stubble after harvest.

SOME DISEASES

Stinking Smut. In the case of bunt or stinking smut two species of fungi may cause the disease: *Tilletia tritici* and *Tilletia laevis* or *foetens*. The former occurs principally in the Pacific Northwest and the latter in the eastern part of the United States. However, the two kinds are so similar that they may be discussed together. Before the heading stage it is next to impossible to distinguish diseased plants from healthy ones. Sometimes after heading, the diseased heads are not very evident except to an experienced person. The smutted heads are of a darker green color, and the stalks are usually shorter than those of the sound heads. The diseased heads have a disagreeable odor and usually appear better filled than healthy ones, but they are deformed and brittle. The chaff is spread by the enlarging of the false kernels or smut balls. On account of their content of greasy black powder or spores, the smut balls give the heads a darker color.

The smut balls are frequently broken in threshing. Thus the spores are released and distributed over the grain, and these spores, if not killed, will infect the next crop. The smut not only affects the value of the grain for seeding purposes but, because of the odor and color, seriously affects the grain for milling purposes. With continuous cropping to wheat the soil may become infected also. Such infection has occurred in the Pacific Northwest. This fact must be taken into account in treating the seeds for sowing.

Control. For the control of the disease, crop rotation, the use of clean seed, seed treatment with fungicides, cultural methods to overcome soil infection, and breeding and selection of varieties are recommended.

Mercury-dust treatments have now replaced the old treatments of copper carbonate and formaldehyde. The mercury dusts used are Ceresan M and New Improved Ceresan, although Ceresan M is rapidly replacing the latter material in treating stinking smut. In making the treatment, about ½ ounce of the dust should be used to each bushel of wheat and thoroughly mixed, preferably in a mixing machine, until each kernel is covered.

Loose Smut. Loose smut is caused by the fungus *Ustilago tritici*. In place of the normal head, a black, sooty mass is produced, which consists of the spores of the fungus. The spores may be blown or washed off, and the naked rachis left. Infection of the plant takes place at blooming time. The spores from the diseased heads are often carried into the

open flowers of healthy heads and lodge on the stigmas. Here the spores germinate and penetrate the embryo without destroying it. As the grain ripens the fungus ceases to grow and lies dormant within the dormant grain. When the grain starts to germinate, the fungus renews its growth, develops with the wheat plant and transforms the flowers of the plant into the sooty spore masses. Thus the significant points in the development of the fungus are as follows: (1) infection takes place only through the open flowers of the blooming wheat head; (2) the fungus is carried from harvest to seeding time inside the grain; (3) when the infected seeds are planted, they produce diseased heads that carry the spores of the fungus.

Control. The treatment most widely used for controlling loose smut is the modified hot-water treatment. This treatment will control both the bunt and loose smuts, whereas the chemical treatments are effective only in case of stinking smut. When the modified hot-water treatment is used, the grain should be soaked in cold water for from 4 to 6 hours and then dipped into hot water at about 120°F. The grain is then soaked for 10 minutes in water at 129°F. The water must be held as close to this point as possible; the temperature should not be allowed to rise above 131°F. or fall below 125°F. The grain should then be spread out to dry on a clean surface. The seeds may be sown as soon as they are sufficiently dry to run through the drill, the rate of seeding being increased to allow for the swelling, or they may be stored when thoroughly dry. The fact that the treatment sometimes lowers the germination should be taken into consideration when seeding.

Black Stem Rust. The black stem rust caused by the fungus *Puccinia graminis* affects wheat, oats, barley, rye, and about fifty cultivated and wild grasses. In the case of wheat this disease is usually more serious on spring than on winter wheat, but it is sometimes more destructive on winter wheat.

The fungus attacks the stems and leaf sheaths but seldom the blades. There are two stages on the grains; the "red rust" or summer stage, and the "black rust" or winter stage. The red rust stage occurs on the younger growing plants, and the black rust stage appears later on the older plants, straw, and stubble.

The disease is carried by the wind to the grain crops from other wheat plants and from its alternate host, the common barberry (*Berberis vulgaris*). It may also pass to some cereals from certain grasses, such as wild barley, quack grass, slender wheat grass, western wheat grass, and the wild rye grasses. The fungus seldom lives through the winter on the living cereal host except in the South.

Control. In the control of the black stem rust disease, the greatest factor is the eradication of the common barberry, as shown by results in this country and in Denmark. Considerable progress is also being made in development of resistant varieties.

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Topics for Discussion

1. Why is wheat the most important bread crop of the world?

2. Do more farmers in the United States grow wheat or corn?

3. Is wheat more or less conducive to soil depletion than corn? Why?

4. Assuming that the wheat crop of the United States should be reduced, in what sections of the country can these reductions most logically be made?

CHAPTER XXI

OATS (Avena sativa)

Oats constitute one of the most important grain crops in the United States, ranking next to corn and wheat in acreage and crop value. In 1939, oats, as compared with the other crops, ranked fourth in acreage and sixth in value.[1] Notwithstanding these facts, too little attention is

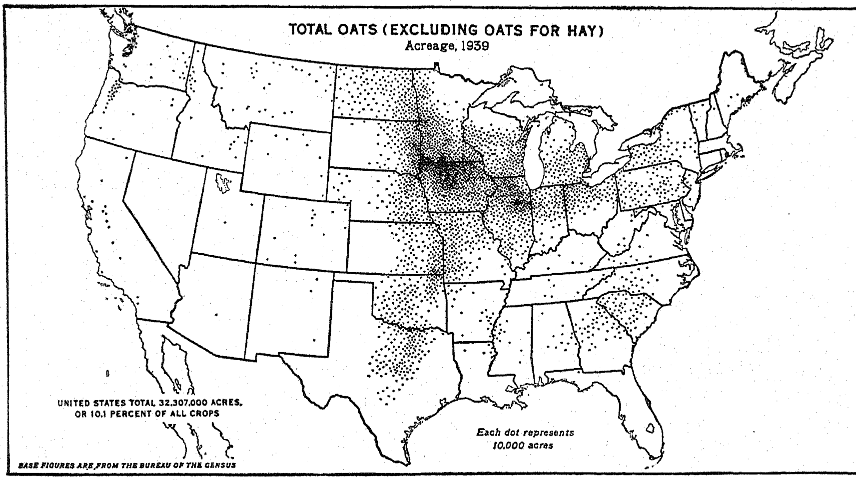

FIG. 45. The valuable bone and muscle-building ingredients contained in oats make them the principal small-grain feed for horses and mules, young livestock, and breeding stock. The principal oat-producing areas in the United States are in the Corn and Spring Wheat Belts where the climate is cool and moist. An area also extends into the Southern plains, and some scattered acreage is found in the South, most of which is made up of fall-sown oats. Acreage of oats in the United States is exceeded only by that of corn and wheat; in 1939 it was about 23 per cent of the world's total. Iowa with 5,001,000 acres, Minnesota with 3,717,000 acres, and Illinois with 3,079,000 acres are the three leading states in acreage of oats. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

given to the production of the crop. The farmer can increase production by using good seed of suitable varieties, seeding early with a grain drill on a well-prepared seedbed, harvesting at the proper time, properly caring for the harvested crop, and clean threshing. The crop is best suited to cool, moist climates.

World Production. During the 10-year period 1935–1944,[2] the United States produced an average of 1,130,613,900 bushels of oats; Germany, 389,400,000 bushels (8-year average); Canada, 401,007,500

bushels; France, 271,396,000 bushels (9-year average); and the United Kingdom, 172,888,500 bushels. These five countries produced about 55 per cent of the world's supply of oats.

The average yield per acre in these countries during 1945 was as follows: United States, 37.3 bushels; Germany (no figures available); Canada, 26.5 bushels; France, 28.0 bushels; and the United Kingdom, 60.5 bushels.

Production in the United States. During the 10-year period 1934–1943,[2] Iowa produced an average of 182,260,000 bushels of oats; Minnesota, 140,307,000 bushels; Illinois, 118,622,000 bushels; Wisconsin, 80,256,000 bushels; and Michigan, 43,233,000 bushels. These five states produced 53 per cent of the oats harvested in this country during this period.

Historical. The origin of the oat, like that of the wheat, is not definitely known. It probably originated in a temperature climate, in eastern temperate Europe or western Asia. It was apparently unknown to the ancient Egyptians, the Hebrews, the Greeks, the Romans, the Chinese, and the people of India, as these people did not cultivate this crop. It was cultivated by the prehistoric peoples of central Europe but probably not until after the cultivation of wheat and barley.

It is believed that oats were not grown in America until after the discovery by Columbus. The crop was grown by the early colonists. In 1839, 123,071,341 bushels were produced in the United States; in 1944 the production was 1,166,392,000 bushels.

The biological origin of the oat is not definitely known, but the prevailing opinion holds that two species—*Avena fatua* and *Avena sterilis*—are the progenitors of nearly all the cultivated oats. The latter species is of more recent origin. The commonly cultivated species of oats, *Avena sativa*, is thought to be descended from *Avena fatua*. Likewise, the cultivated red oat, *Avena byzantina*, is believed to be descended from *Avena sterilis*, the wild red oat.

Classification. There are nine species of oats listed as follows:

Avena
- *nuda*, Hull-less oats
- *sterilis*, Wild red oats
- *byzantina*, Cultivated red oats
- *Abyssinica*, Abyssinian oats
- *strigosa*, Rough or sand oats
- *brevis*, Short oats
- *fatua*, Wild oats
- *sativa*, Common oats
- *sativa orientalis*, Common side oats

The oats to be considered in this discussion are those belonging to the *sativa* species. Oats are sometimes grouped according to shape of head or panicle, color of seed, time of seeding, and date of maturity.

Shape of Head. In the common oat the panicle is rather upright, and the branches are usually about equally distributed on all sides. This is frequently described as the "spreading oat." In the case of the common side, or "horse-mane," oat the branches of the panicle fall to one side, hence the name "side oat."

The side oats seem to be somewhat more restricted in their adaptation than common oats. As a rule side oats do not produce as large yields as spreading oats under the same conditions. In case of side oats there are only spring varieties.

The common oats include most of the cultivated varieties. They differ from each other in diameter and height of straw; form and size of panicle; presence or absence and type of awn; form, size, and color of kernel; time of maturity; and other characteristics. There are both winter and spring varieties.

Color of Oats. Oats may be classified as to the color of the hull. The five principal colors are white, black, red, yellow, and gray. In the North the oats commonly grown are white, but black, gray, and yellow varieties are also grown. In the South the red and gray oats are chiefly grown.

Time of Seeding. Oats may be classified as spring and winter, according to the time of seeding. Winter oat production is limited primarily to the southeastern portion of the United States and the Pacific Coast states. Nine-tenths of the oat crop is spring-sown. Often the same variety is sown either in the fall or in the spring, and a variety seeded in the fall in the South may be seeded in the spring farther north. The fall-sown oats ripen a month to 6 weeks earlier than the spring plantings.

Days to Maturity. Oats are sometimes grouped as early and late, according to the days from time of planting to maturity. Some varieties mature 10 days to 2 weeks later than other varieties.

Hull-less Oats. These oats, which are also called "Chinese hull-less," are but little grown in the United States. They do not yield well and are usually grown as a curiosity. In the threshing process, the kernel separates from the hull. Liberty, a hull-less variety developed in Canada, is the most common in the United States.

Varieties. There are many varieties of oats adapted for all oat regions. Many of these varieties are old, tried, and true. Some varieties are the parents of crosses that have meant much to the oat industry. Stanton[3] lists new disease-resistant oat varieties that have been developed and are well received.

In the Corn Belt states, Boone, Control, Tama, Vicland, Cedar, and Vikota are grown almost to the exclusion of other oat varieties. These were crosses from Victoria and Richland varieties. They have a combination of resistance to the rusts and smuts, high yield, and quality.

It is estimated that they were grown on two-thirds of the entire oat acreage in 1946. Clinton and Benton are selections from a mating with Iowa D 69 and Bond. These two new varieties are very promising as they have greater productivity, higher test weight, better resistance to crown and stem rusts, and much stiffer straw than Boone, Vicland, and Tama.

In the Southwest, promising new varieties are Osage, Neosha, and Ventura. These varieties appear to be well adapted to the climate of Kansas and Southwestern states where red oats are grown.

For fall seeding in the South, some of the promising new winter varieties have come from a cross between Lee and Victoria. The varieties developed and distributed from this cross are Letoria and Lelina in North Carolina; Stanton in South Carolina and other Southern States; Lega, Lelate, Levic, and Leroy in Georgia; Florilee in Florida; and DeSota in Arkansas. They have less hull and better grain characters than many of the old varieties. Traveler is a promising new variety, resistant to crown rust and smut, developed from a Victoria-Custis cross at the Arkansas Experiment Station.

Other promising oat varieties for the South include Quincy Red, Fultex, Victorgrain, Fulgrain, Ranger, Rustler, Rangler, Carolina Red, Quincy Gray, Verde, and Camellia.

Uses. The oat crop was once used chiefly as a grain feed for horses. Owing to the advent of the automobile and tractor, oats are, however, being fed more and more to dairy cattle, young stock, sheep, and hogs. In very recent years oats are being hulled at local mills and elevators as feed for hogs and poultry. When in the milk stage, the crop is sometimes cut for hay.

The oat kernel is also used for making oatmeal for human consumption. In the manufacture of oatmeal, the hull is a by-product which is sometimes mixed with other materials for making feed for livestock.

CULTURE

Seed. The grower should attempt to use good seed of the variety best adapted to the region in question. There has been considerable improvement made with the oat crop along breeding lines. The improved strains should receive consideration by the grower.

The selection of seed oats by the use of the fanning mill has not proved very profitable, but, when the seed is selected by hand so as to secure a comparatively large difference in size of seed, the yield from heavy seed is usually more than that from light seed. These results do not mean that the fanning mill should not be used, since its use is valuable in the removal of inert matter, diseased seeds, and certain foreign seeds.

Rate of Seeding. Fall-sown oats give more consistent yields when seeded heavy than when seeded light. Most often oats are sown in the Great Plains area at rates varying from 4 to 8 pecks per acre. The rates of seeding oats in the Great Plains usually are not so heavy as in sections farther east, where the rainfall is greater and less danger of drought exists. In the Pacific area the usual rates of seeding are from 10 to 12 pecks per acre, although seedings of 14 to 16 pecks are sometimes made. The seeding rate for oats in the irrigated sections varies from 8 to 12 pecks per acre. When oats are used as a nurse crop, the seeding rate should be reduced by at least one-fourth. Rather heavy rates of seeding for winter oats usually are necessary to ensure a satisfactory spring stand, especially in areas where winterkilling is likely to occur. As a rule it pays to sow 8 to 10 pecks an acre, although in the milder parts of the South a 6-peck rate is frequently ample, especially when the oats are seeded at the optimum date in a fertile, well-prepared soil (Stanton and Coffman[4]).

Time of Seeding. In case of both kinds of oats, early seedings are important. For best results fall oats should be seeded about 30 days before the usual date of the first killing frost. Spring oats should be seeded as soon as practicable in the spring. Late seeding has been one of the most frequent causes of failure with the crop. Winter oats should be seeded early enough to give the young plants time to make sufficient growth to be well established before the occurrence of severe freezing weather.

Methods of Seeding. The proper distance between drill rows in seeding small grains has frequently been discussed. It is often claimed that a 4-inch row is better than an 8-inch row, as the plants are better distributed. The use of the grain drill in seeding winter oats is strongly recommended. Drilling produces a more uniform stand and more even germination and growth than broadcast seeding. Drilling requires less seed, and, as the seed is uniformly placed in the soil at a favorable depth, the plants are less subject to winterkilling than when the seed is broadcast. Drilling at least 3 inches deep on well-prepared land, leaving the drill furrows as open as possible, is advised (Stanton and Coffman[5]).

Cultivation. It is doubtful whether the cultivation of oats will pay except in dry years; and even then the crop will succeed best when drilled. The practice is not generally followed.

SOME DISEASES

Among other diseases, the oat crop is affected by loose smut (*Ustilago avenae*) and covered smut (*Ustilago laevis*). These two smuts may be

considered as one from the economic standpoint, since they are similar in appearance and since both are controlled by the same treatment.

The loose smut of oats is very similar to loose smut of wheat in appearance. All parts of the flowers are affected and turn into black, sooty masses of spores. The covered smut of oats differs from the loose smut of oats in the less complete destruction of the flower parts and in less profuse production of spore masses, which are somewhat blacker than those of loose smut.

Infection of the two smuts takes place in a manner similar to that of bunt of wheat, both in the field and in threshing. The spores are retained on the surface of the grain. If not destroyed, they germinate in the soil with the seeds and thus infect the young plants. These in turn produce smutted heads.

The mercury-dust treatment as given for bunt or stinking smut of wheat is usually recommended.

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Topics for Discussion

1. Why is the oat crop of major importance in Europe and of minor importance, compared with other cereals, in the United States?

2. Do oats have any important characteristics that make them better for animal feed than other cereals?

3. Compare the water required, plant food removed, and amounts of dry matter and digestible nutrients produced in a 25-bushel crop of wheat and oats.

4. Should the oat crop of the United States be decreased or increased? Of your section?

CHAPTER XXII

BARLEY (Hordeum vulgare)

The area suitable for the profitable production of barley in the United States is less extensive than that for corn, wheat, or oats. However, the crop deserves more attention than it has received. In 1939,

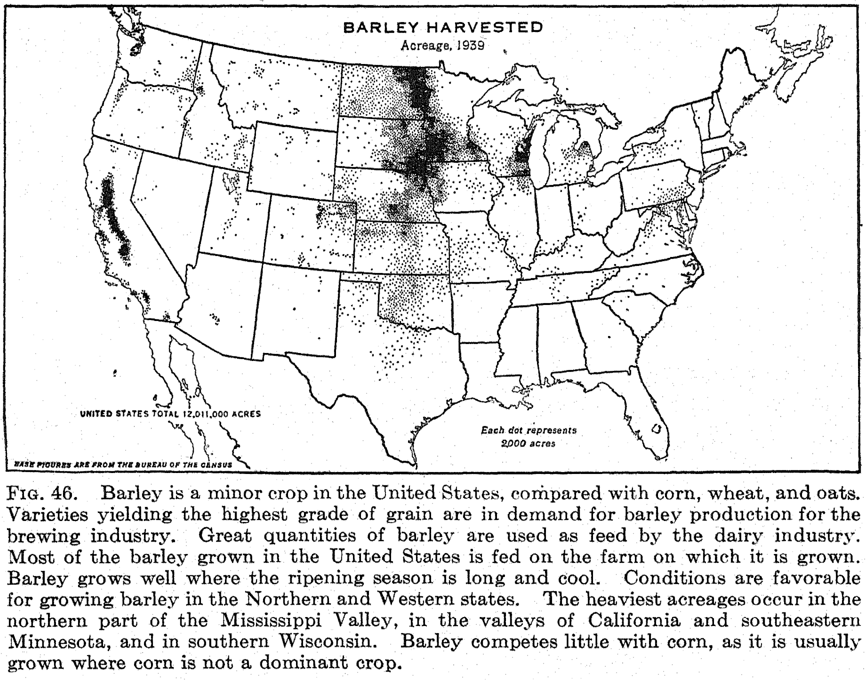

FIG. 46. Barley is a minor crop in the United States, compared with corn, wheat, and oats. Varieties yielding the highest grade of grain are in demand for barley production for the brewing industry. Great quantities of barley are used as feed by the dairy industry. Most of the barley grown in the United States is fed on the farm on which it is grown. Barley grows well where the ripening season is long and cool. Conditions are favorable for growing barley in the Northern and Western states. The heaviest acreages occur in the northern part of the Mississippi Valley, in the valleys of California and southeastern Minnesota, and in southern Wisconsin. Barley competes little with corn, as it is usually grown where corn is not a dominant crop.

barley ranked seventh in acreage and ninth in value as compared with the other crops.[1]

World Production. During the 10-year period 1935–1944,[2] China produced an average of 343,158,000 bushels of barley (average of 5 years); United States, 289,598,400 bushels; Germany, 152,283,500 bushels (average of 8 years); India, 101,407,000 bushels; and Turkey, 86,949,300 bushels. These five countries produced approximately 42 per cent of the world's supply during that period.

During 1945 the average acre yields in those countries are as follows: China, no figures available; United States, 25.9 bushels; Germany, no figures available; India, 16.5 bushels; and Turkey, 11.8 bushels.

Production in the United States. During the 10-year period 1934–1943,[2] Minnesota produced 44,401,000 bushels of barley; North Dakota, 33,018,000 bushels; California, 32,754,000 bushels; South Dakota, 28,353,000 bushels; and Nebraska, 20,160,000 bushels. These five states produced about 58 per cent of the entire crop of barley in this country during that period.

Historical. Barley has been known for thousands of years, and it was cultivated before any recorded history of man. During its early cultivation it was used for making bread, beer, and feed for beasts and was used by the people of Europe as the chief bread material until as late as the sixteenth century. Barley is supposed to have originated in Abyssinia and southeastern Asia.

Barley was grown by the early colonists in the United States. In the early part of the seventeenth century it was grown in Massachusetts and Virginia, and later in the same century it was grown in Rhode Island and New York. In 1839, 4,161,504 bushels of barley were grown, whereas in 1944 the production was 278,561,000 bushels.

The biological origin of barley is not definitely known. The six-row barley is probably the form first cultivated. The oldest form now known to be growing wild is *Hordeum spontaneum*, a species very similar to the present two-row barley.

Classification. The classification as given by Aberg and Wiebe[3] is as follows:

$$\textit{Hordeum}\begin{cases} \textit{vulgare}, \text{ Six-row barley} \\ \textit{distichon}, \text{ Two-row barley} \\ \textit{irregulare}, \text{ Two-row barley} \end{cases}$$

The classification as given is based on the number of rows of grain and their arrangement.

Hordeum vulgare, a six-row barley, is widely grown in the United States and is the most important species. In this species all three spikelets at each node of the spike are fertile. There are dense and lax forms, depending upon the length of the rachis internodes.

Hordeum distichon, a two-row type of barley, is grown rather widely in the United States. Only the median spikelets are fertile. Although the lateral spikelets are infertile, they possess all the floral organs.

Hordeum irregulare, an irregular barley with tough rachis, seems to have originated in Abyssinia. The central florets are fertile, whereas the lateral florets are reduced to rachilla in some cases, and these are dis-

tributed irregularly on the spike. The remainder of the lateral florets are either fertile, sterile, or sexless.

Types of Awns. Wiggans[4] has divided barleys into three types in regard to the awn characters: (1) awned or bearded barleys, (2) awnless or beardless barleys, and (3) hooded barleys.

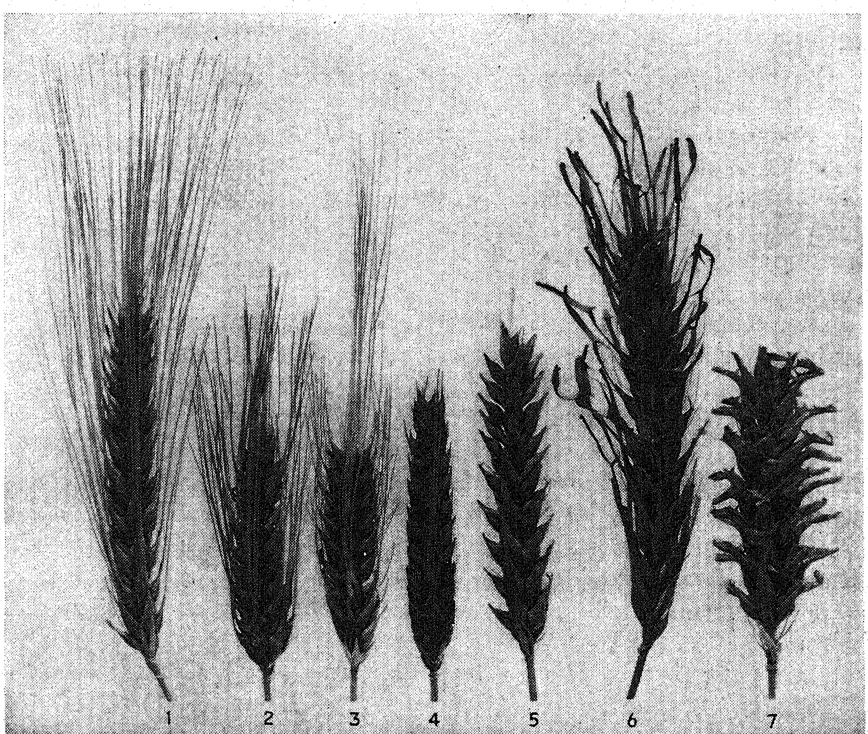

FIG. 47. Barley awn types. *Left to right:* (1) Long awns, (2) short awns, (3) short awns on central rows, awnletted on lateral rows, (4) awnletted on central rows, awnless on lateral rows, (5) awnless, (6) elevated hoods, (7) sessile hoods. (*Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S. Dept. Agr.*)

The awn may be barbed or smooth. Most varieties of barleys hold their awns, but some lose them when the grain ripens. The awnless or beardless barley should not be confused with the hooded barleys. In the case of hooded barleys, the normal awn is replaced by a trifurcate structure called the "hood."

Color of Grain. Aberg and Wiebe[3] state that there are three colors in barley: white, blue, and black. The black color is due to a melaninlike substance. The blue color is due to anthocyanin, a common plant pigment that in barley kernels appears as blue in the aleurone and as red in the pericarp and hull.

Winter and Spring Barleys. There are both winter and spring types of barley. The latter type is grown more extensively in the United States. Winter barley is less resistant to cold than winter wheat or winter rye, and its production is limited to the southeastern section of the country.

Hull-less Barleys. Generally, the barley kernel is surrounded by a hull, and in such a case the kernel and hull together constitute the grain. However, in each of the main groups, both hull-less and hulled varieties are found.

Varieties. There are many varieties of barley. To this list more than twoscore varieties have been released in the past decade. According to Wiebe,[5] they average 3 to 5 bushels more grain to the acre than the ones they replace. Often the new kinds have other advantages, like greater resistance to smut, rust, mildew, scald, spot blotch, stripe, and other diseases; greater winter hardiness; resistance to insect attack; greater tolerance to drought; stronger straw; and smooth awns. Most varieties have smooth or semismooth awns, and most are six-rowed.

New spring varieties of barley that have been developed and released in various states are listed as follows:

Arrivat (Ariz.), Beecher (Colo.), Glacier (Mont.), Gem (Idaho), Kindred (N.D.), Compana (Mont.) (two-row), Rojo (Calif.), Bay (Mich.), Mars (Minn.), Tregal (N.D.), Velvon and Velvon II (Utah), Lico (Colo.), Flynn 37 (Oreg.), Flynn I (Kans.), Belford (Wash.) (Hooded), Rufflyn (Wash.), and Munsing (Colo.) (two-row). Winter varieties of barley have also been improved either by breeding or selection and released as follows:

Davidson (N.C.), Texan (Tex.), Santiam (Oreg.), Cascade (Oreg.), Wong (N.Y.), Sunrise (N.C.) (awnless), Calhoun (S.C.) (awnless) Marett Awnless 1 (S.C.) (awnless), Smooth Awn 86 (Va.), Jackson and Jackson I (Tenn.), Tenkow (Okla.), Fayette (Ark.), Reno (Kans.), Ward (Okla.), Woodwin (Okla.), Brier (W. Va.), Randolph (N.C.), Wintex (Tex.), New Mexico Winter I (N.M.), Iredell and N.C. Hooded 26 (N.C.) (hooded), and Tucker (W. Va.) (hooded).

Introduced varieties of barley include Tunis (Tex.), Olympia (Wash.) and Poland (N.Y.).

Malting Barley. For malting, barley must have plump, mellow, small kernels, with small hulls that are not easily damaged. The barley grains should be of the same type, sound, and free from weather and disease damage. Broken and skinned kernels are objectionable as malt barleys. Black varieties are also objectionable. Mealy barley grains contain about 10 per cent protein, whereas the hard or vitreous kernels contain 12 to 14 per cent protein. For malting purposes, a low-protein

barley is more desirable. In general the six-row barleys are higher in protein than the two-row types.

The grain should germinate uniformly, quickly, and completely; be free from discoloration; and preferably be of a bright straw color, having a good percentage of hull.

In this country barley is now chiefly used as a feed crop. For this purpose the question of germination is not so important so long as the grain is of good quality.

Uses. Barley is used for malting, pearling, breakfast-food preparations, and flour. Barley is coming into greater prominence as a stock feed since its use for malting purposes has decreased. It has proved to be a good grain feed and is used in many instances to take the place of corn. Although barley is somewhat higher in protein than corn, it is also carbonaceous. It is, therefore, a good plan to feed it in connection with feeds high in protein.

CULTURE

Seed. It is important to choose the varieties best suited to the region in question. A superior grade of seed, of the variety chosen, is of great value in securing large yields. The farmer should clean the seeds with a fan mill or seed cleaner before planting. This operation will remove much of the inert matter, weed seeds, and lightweight and diseased seeds.

Time of Seeding. In general, winter barley should be seeded after winter oats and before winter wheat. The usual time is 2 weeks before the first frost in the fall. Spring barley should be seeded at the same time that spring wheat is sown, if maximum yields are to be expected. In the Northern Plains the most favorable time of seeding is from April 1 to 25. A loss of at least 1 per cent per day is to be expected for each day the seeding is delayed after April 25 (Harlan[6]).

Rate of Seeding. Harlan[6] states that in humid sections 2 bushels of barley are usually seeded per acre. In the Northern Plains 4- and 8-peck seedings have given about equal returns. The usual recommendation is 4 to 6 pecks. In dry years 4 pecks are sufficient. In the driest portion of the Dakotas, in Montana, and in the Great Basin, 3 pecks frequently give good results. In California 7 pecks are generally used. In case hull-less varieties are used, the rate of seeding is about three-fourths that of hulled seed.

Depth of Seeding. Harlan[6] states that in humid regions barley should be seeded about 1½ inches deep. In the Northern Plains the depth should be about 2 inches; in the Great Basin, 2½ to 3 inches.

Method of Seeding. As with wheat and oats, drilling barley gives better results than broadcasting the seed.

SOME DISEASES

There are two smuts of barley that correspond to the loose smut and bunt of wheat. The smuts that affect barley are called "loose smut" and "covered smut," and they are caused by the fungi *Ustilago nuda* and *Ustilago hordei*, respectively. These two fungi attack only the barley plant.

Loose Smut. The loose smut of barley is very much like the loose smut of wheat in appearance, the entire head being destroyed. The life history is identical with that of the loose smut of wheat fungus, the infection taking place only when the barley heads are in flower.

The hot-water treatment will control this disease, and the same method is used as for wheat except that a lower temperature is advisable. The temperature of the water should be 126°F. (admissible range 124 to 129°F.) and the time of exposure should be 13 minutes. The period of presoaking in cold water should be as for wheat, about 4 hours.

Mercury dust also will control loose smut. It is much safer to use than the hot-water treatment. The dust should be thoroughly mixed with the seed, using 3 ounces of dust to each bushel of seed.

Covered Smut. The covered smut of barley is somewhat like bunt of wheat in appearance. However, the diseased heads have no odor, and they are more completely destroyed than bunted heads of wheat. The diseased heads have a dark-gray color when mature, usually appear later, and are borne on shorter stalks than normal heads. Often they scarcely emerge from the boot. In the threshing process, the smut balls are broken, and the spores contaminate the healthy seeds. The life history of the covered smut of barley is similar to that of bunt of wheat, and the mercury-dust treatment used on bunt will control the covered smut of barley.

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Topics for Discussion

1. What has caused the rapid increase in acreage of barley in the South and the East in recent years?

2. Compare rye and barley as to production of grazing, dry matter, and digestible nutrients in your state.

3. How do you explain the fact that barley is used more extensively than other cereals for brewing purposes?

4. Compare barley with other cereals in resistance to adverse weather conditions in your section.

CHAPTER XXIII

RYE (Secale cereale)

Rye is hardier than wheat and will grow on some lands not suitable for wheat. It is well adapted to the same regions as wheat and also may be grown farther north from fall seeding.

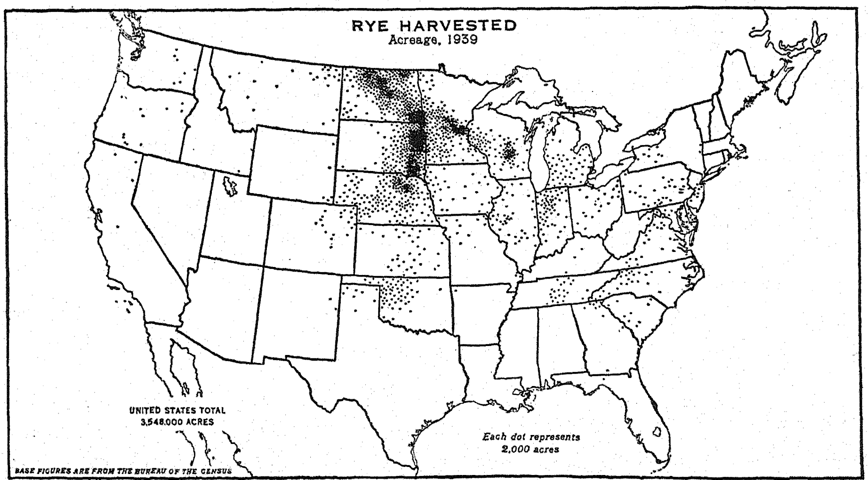

FIG. 48. The principal acreage of rye for harvest is located in the sandy and fine sandy loam soils of the subhumid areas of the northern Great Plains. In 1939, the three leading states in acreage of rye were North Dakota, with 779,000 acres, South Dakota, 616,000 acres, and Minnesota, 490,000 acres. Rye can be grown where winters are too severe even for winter wheat. It is used as a green manure, winter cover, and pasture crop, and because it grows so well on sandy and other relatively infertile soils, it is used extensively as a "catch crop." About 60 per cent of the harvested rye crop is used for feed and seed; a little more than half of the remaining 40 per cent is used for flour; and the remainder is utilized in the distilling industry. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

World Production. During the 10-year period 1930–1939,[1] Germany produced an average of 612,428,000 bushels; Poland, 518,169,000 bushels; Czechoslovakia, 132,626,000 bushels; United States, 75,740,000 bushels; and France, 62,034,000 bushels. These five countries produced about 40 per cent of the entire amount grown in the world.

The average yields per acre during that same period were as follows for these countries: Germany, 27.8 bushels; Poland, 18.1 bushels; Czechoslovakia, 26.9 bushels; United States, 11.4 bushels; and France, 18.5 bushels.

Production in the United States. During the 10-year period 1934–1943,[1] North Dakota produced an average of 8,346,000 bushels of rye; South Dakota, 6,751,000 bushels; Minnesota, 5,197,000 bushels; Nebraska, 3,879,000 bushels; and Wisconsin, 2,559,000 bushels. These five states produced approximately 64 per cent of the entire crop grown in the United States during that period.

Historical. Rye has not been under cultivation so long as wheat or barley. It was unknown to the ancient Egyptians and Greeks and to the lake dwellers of Switzerland. Its introduction into the Roman Empire was scarcely before the Christian Era. It seems to have been cultivated first in western Asia and southern Russia. It may also be noted that five or six species of the genus *Secale* are to be found in these sections of the world.

Rye was grown in the United States by the early colonists at least as early as 1625. In 1839 the production was 18,645,576 bushels, and in 1945 the production was 26,354,000 bushels. The original species of rye is supposed to be *Secale montanum*, a perennial grass.

Classification. The classification as given by Carleton[2] is as follows:

$$\textit{Secale}\begin{cases}\textit{fragile}\\ \textit{montanum}\begin{cases}\textit{dalmaticum}\\ \textit{anatolicum}\\ \textit{cereale}\end{cases}\end{cases}$$

Secale cereale is the only species of importance under cultivation. The grains of rye may be yellow, gray, green, or grayish brown. There are both winter and spring ryes, but approximately 99 per cent of the crop is fall sown.

Varieties. Where winter hardy varieties are needed, such as in Montana and North Dakota, the Dakold variety has given good results. Rosen rye is well adapted to the conditions in and around Michigan. In the southern part of the country, where the winters are not too severe, the most popular varieties are Abruzzi and Balbo.

In the more northern sections of the country, rye is grown for grain. In the Cotton Belt, rye has a wide use as a green-manure and pasture crop.

Uses. Of the rye produced in the United States from one-fourth to three-fourths is exported; a little is used as feed for domestic animals; the remainder is used for making flour and alcohol. The straw is important in the manufacture of paper and horse collars, in packing, and in providing bedding for animals. In some sections the crop is raised more for the straw than for the grain. Rye finds a wide use, especially in the Southern states, as cover, green-manure, and grazing crops.

CULTURE

Seed. Usually too little attention is given to the selection of well-adapted varieties and good seed in the production of the rye crop. There is a great difference in yielding ability and habit of growth among the varieties. A variety adapted to the conditions and the purpose for which it is to be used should be chosen. Varieties from the North are especially unsuited in the South.

It is well to fan or clean the seed to remove the small, immature, and diseased grains and the seeds of noxious weeds. However, large seeds of rye, as separated by the fanning mill, yield no more than the small seeds so separated.

Time of Seeding. Spring rye should be sown at the time spring wheat is seeded; *i.e.*, as soon as the ground can be worked. The time of seeding winter rye will depend on the use to be made of the crop. If the crop is to be used for pasture, for green manure, or as a cover crop, it should be sown from 2 weeks to a month earlier than if it is to be used for grain. In the South the highest yields of grain are obtained when seeded at the time most favorable for wheat production.

Rate of Seeding. If the crop is to be used for pasture or green-manuring purposes, the rate of seeding is somewhat heavier than if it is to be used for grain. The usual rate of seeding for grain production in the Eastern states and under irrigated conditions is 6 pecks per acre, in the Southwestern states and in semiarid sections, 3 or 4 pecks; and under subhumid conditions, 5 pecks. The usual rate of seeding, when the crop is to be used for pasture, green manuring, or soiling, is 2 bushels per acre.

Depth and Method of Seeding. The usual depth of seeding is from ½ to 2 inches. The depth will vary with the type of soil and season. On sandy soils and in dry seasons the seed should be placed deeper than when the conditions are the reverse.

Better results are usually secured from seeding with the grain drill than from broadcasting the seed. The former method is almost universally practiced.

SOME DISEASES

The rye plant is subject to attack of black stem rust (*Puccinia graminis secalis*), brown leaf rust (*Puccinia dispersa*), stem smut (*Urocystis occulta*), anthracnose (*Colletotrichum cereale*), ergot (*Claviceps purpurea*), and other diseases. The diseases that usually cause the greatest losses are anthracnose and ergot.

Anthracnose. Anthracnose manifests itself by the premature dying of the portion of the head above the point of attack. In the dead portions

there is almost a total loss of grain. The roots and lower portions of the stems are also attacked; and this attack results in a blackened appearance of the affected parts, in a loss in vigor of the diseased plants, which have a tendency to break over, and in the production of shriveled grain. No control remedy is known, but there seems to be some difference in varietal susceptibility. Abruzzi, Florida, and Tuscaloosa are said to be somewhat less susceptible than other varieties.

Ergot. Ergot is the most serious and destructive disease affecting rye. The disease is caused by an attack on the ovary by the fungus while the plant is in bloom. The ovary is penetrated and replaced by an ergot sclerotium, which is a horny black or purplish body several times larger than the seed of the affected plant. The ergot sclerotia germinate and produce spores that infect susceptible plants in the blossoms and produce new ergot sclerotia. Ergot also occurs in timothy, Kentucky bluegrass, and many other grasses.

Control. In the control of the disease, ergot-free seeds are necessary. Rye should not follow rye in the rotation if ergot is present, and ergot may be removed from rye by passing the grain through a 20 per cent solution of common salt. The rye grains will sink while the ergot sclerotia will float. The grain is then rinsed in fresh water. The treatment does not injure germination, and the seeds may be sown as soon as the water has drained.

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Topics for Discussion

1. Why is rye not used extensively for breadmaking in this country?

2. How does rye rank as a feed grain as compared with other cereals?

3. Show which sections of the country use rye more extensively for ground cover and pasturage than for grain production. What is the probable reason for this?

4. Rye is said to be "hard on the land" as compared with other cereals. Is this true? If so, is this a sufficient reason for not growing rye?

SECTION III

LEGUMES FOR SEED

CHAPTER XXIV

PEANUTS (Arachis hypogaea)

The peanut, also known as "goober," "goober pea," "ground pea," "groundnut," and "pindar," is an important crop in about a dozen states in the South. It is, properly speaking, a pea rather than a nut. The

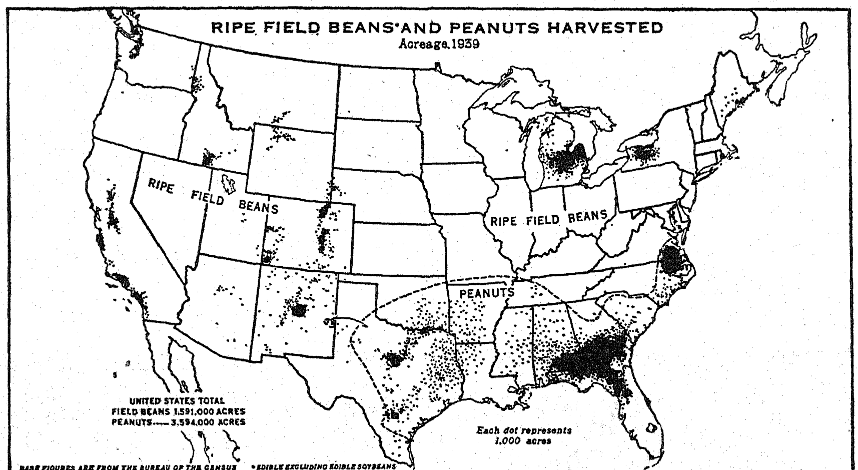

FIG. 49. The leading varieties of field beans in the Ontario-Honeoye soil area of western New York, and in the Saginaw Valley and adjacent uplands of southern Michigan, are the White Pea, Robust, and Wells Red Kidney beans; in eastern Colorado and New Mexico varieties grown are mostly native Mexican or pinto beans. In California, commercial limas, white beans, and blackeye beans are raised, and in areas of Idaho, Montana, and Wyoming, Great Northerns and other varieties are grown. The greatest area of peanut production lies in Alabama, Georgia, and Florida where the smaller Spanish variety is grown. It is used mostly as feed for stock or is made into oil and peanut butter. Peanuts from the Virginia-North Carolina district are used mostly for human consumption. The peanut market at Suffolk, Virginia, is the largest in the world. (*U.S. Dept. Agr. Bur. Ag. Econ.*)

term "nut" has perhaps been added, since the pea has a shell and a flavor similar to the shells and flavors of many true nuts.

World Production. During the 10-year period 1935–1944,[1] India produced an average of 6,998,208,000 pounds of peanuts, or approximately 37 percent of the world's supply; China, 3,890,468,400 pounds; and the United States, 1,587,964,000 pounds.

Production in the United States. Peanut production on a commercial scale is limited to the Southern states. The bulk of the peanut crop produced in Virginia and North Carolina is used for human consumption, while the peanuts grown in the states farther south are to a great extent "hogged off" or used for the production of oil.

During the 10-year period 1933–1942,[1] Georgia produced an average of 421,750,000 pounds of peanuts; North Carolina, 275,038,000 pounds; Alabama, 206,362,000 pounds; Virginia, 160,624,000 pounds; and Texas, 144,255,000 pounds. However, during the next 2 years, 1943 and 1944, the states ranked in the following order in production: Georgia, Alabama, North Carolina, Texas, and Virginia. Also the average production in the United States increased from an average of 1,341,811,000 pounds in 1933–1942, to 2,110,775,000 pounds in 1944.

Historical. The peanut originated in America and is probably a native of Brazil, since six or seven closely allied species are found there. The fact that seeds were found in Peruvian tombs at Ancon indicates its antiquity in America.

The peanut was brought to the United States during the early days of colonization, but it did not become commercially important until about 1870. The growth was gradual from that time to about 1900, when the cultivation received a rapid impetus due to the spread of the boll weevil in the South. In 1909 there were 870,000 acres of peanuts grown—an increase of 68 per cent over the production of 1900. In 1929 there were 1,262,000 acres harvested; in 1934, 1,514,000 acres; in 1939, 1,906,000 acres; and in 1944, 3,150,000 acres.

Classification. Peanuts may be divided into two types: large podded and small podded. These types are subdivided into bunch and runner sorts. There are in all nine or ten distinct varieties of peanuts grown in the United States. Peanuts may be classified as follows:

Size of Pods	Type of Growth	Varieties
Large	Runner	Virginia Runner North Carolina Dixie Runner Holland Jumbo Jumbo African
	Bunch	Virginia Bunch
Small	Bunch	Spanish Small Spanish Improved Spanish Valencia Tennessee White Tennessee Red Georgia Red

In the bunch type the pods are clustered about the base of the plant. In the runner type the pods are scattered along procumbent rooting stems. The large-podded varieties are used chiefly for roasting and confectionery purposes. The small-podded kinds are used for shelling, oil making, and hog feeding.

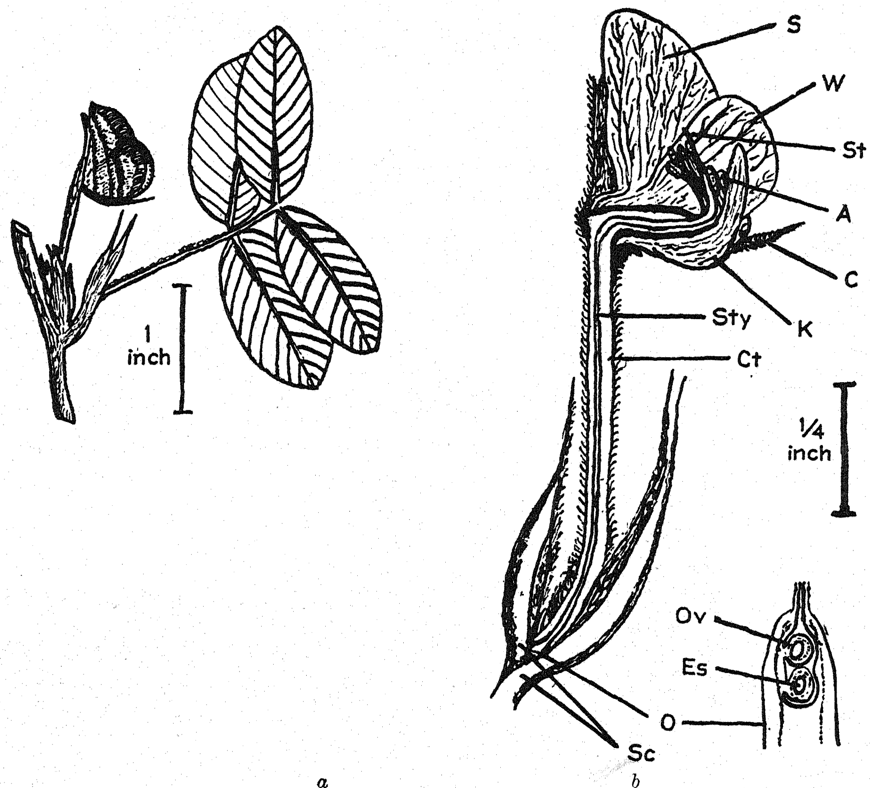

FIG. 50. (*a*) Peanut flower and buds as they occur in the leaf axil. (*b*) Enlarged sectional drawing of same flower: *S*, *W*, and *K* are flower petals; *St*, stigma; *A*, anthers; *C*, calyx; *Sty*, style; *Ct*, calyx tube; *Ov*, ovule; *Es*, Embryo sac containing the egg cell; *O*, ovary; *Sc*, bud scales. (*Sixty-sixth Annual Report*, *N.C. Agr. Expt. Sta.*, 1943.)

In southeastern Virginia and northeastern North Carolina the Virginia Bunch and Virginia Runner varieties predominate. In the Gulf Coast region, Oklahoma, and Arkansas, the Spanish variety is most widely grown.

The Virginia Runner and Virginia Bunch varieties weigh 22 pounds to the bushel, the Spanish variety weighs 30 pounds, while other varieties range between these weights according to the size and filling of the pods.

Regions. The peanut will adapt itself to a wide range of climate if the soil conditions are favorable. The preferable climate is one with a

growing season of 120 to 140 days, moderate rainfall during the growing season, plenty of sunshine, and a comparatively high temperature. Usually the best results are secured when the average annual rainfall is from 42 to 54 inches, but the crop can be produced with more or less water than this amount.

Light sandy loam soil is the most suitable kind for the production of the largest quantity of marketable peanuts to the acre. Sandy soils produce, other things being equal, peanuts of the highest quality, but the yields are somewhat better on the sandy loams. Dark-colored soils stain the hulls and lower the market price. When the peanuts are not to be sold, but are to be used for hog feeding or some similar purpose, almost any kind of soil, with the exception of the very heavy types, may be used. For peanut growing it is very essential that the soil be well drained.

Beattie and Beattie[2] state that peanuts should be grown in a definite rotation, including at least two soil-improvement crops, such as cowpeas, velvet beans, soybeans, bur clover, crimson clover, vetch, or any crop that will add organic matter to the soil. Peanuts should not be planted on the same land oftener than once in 3 or 4 years.

Composition. According to results secured by Batten,[3] in Virginia, the percentage of shell or hull in the Virginia Bunch variety is 26.92 per cent; Virginia Runner, 14.70 per cent; and Spanish, 17.74 per cent.

The composition of the different portions of the peanut plant and some of its by-products is shown in Table 17. The analyses of the hay and vines are taken from Brown[4], and the remainder are from Reed.[5]

TABLE 17. CHEMICAL COMPOSITION OF THE PEANUT AND SOME OF ITS BY-PRODUCTS

Peanut	In water-free substance, per cent					
	Water	Ash	Protein	Fiber	Nitrogen-free-extract	Fat
Hay	7.83	17.04	11.75	22.11	46.95	1.84
Vines	6.25	6.02	13.48	29.16	36.28	15.06
Whole peanut	6.20	4.00	36.60	24.30	21.50	7.30
Hulls	7.90	3.00	6.80	62.30	17.10	2.90
Cake and meal	7.30	5.60	46.90	9.50	22.40	8.50
Skins	7.10	3.20	16.90	10.80	37.50	24.60
Germs	5.60	3.10	29.10	4.50	12.00	45.40
Meat	4.80	2.40	29.80	2.80	12.90	47.20

The peanut is an inexpensive source of thiamin and niacin, two important B vitamins.

Botanical. The peanut (*Arachis hypogaea*) is a member of the Papilionaceae or pea family. It is an annual, and the plants grow from 1 to 2 feet high and produce angular, hairy stems with spreading branches. Some of the varieties produce branches that are comparatively long and prostrate, and those of other varieties are short and upright. The small yellow flowers are borne at the joints where the leaves are attached to the stems, and as soon as pollination takes place the flower fades and the "peg," as it is commonly called, elongates and goes into the soil, where the pod develops. Hence it is essential that the crop be grown on soil where a loose surface can be maintained (Beattie and Beattie[2]). The plant has a small taproot with many strong branches. The roots are cinnamon yellow in color and usually abundantly supplied with nodules.

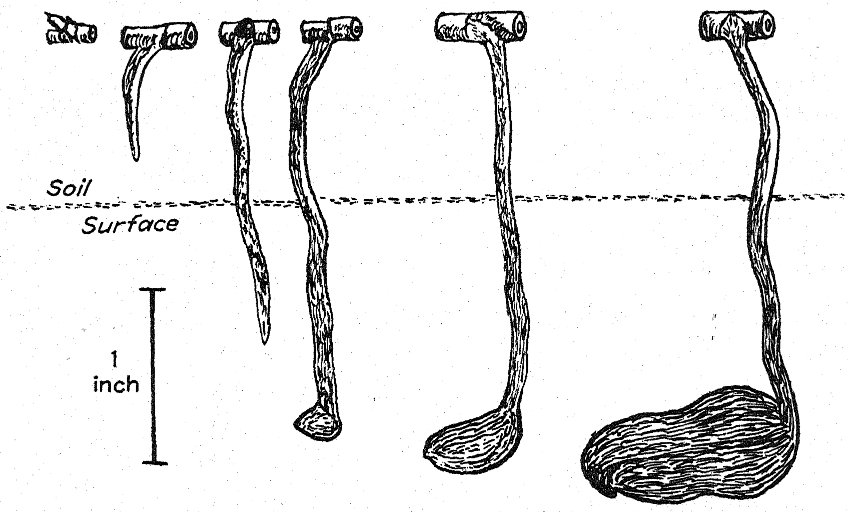

FIG. 51. Six stages in the development of a peanut peg; ovary to mature pod. (*Sixty-sixth Annual Report, N.C. Agr. Expt. Sta.*, 1943.)

Uses. The crop is used in a great number of ways, and its importance is increasing. As a human food the peanut is not only eaten from the shell, but also in the form of salted shelled peanuts and blanched peanuts. It is also used in candies and brittle and in the form of butter. Large quantities of oil are also expressed from the seed.

Peanut butter is a highly nutritious food, since it contains 29.3 per cent protein, 46.5 per cent fat, 17.1 per cent carbohydrates and 5 per cent ash, and has a food value of 2,825 calories per pound.

Peanut oil is used extensively at the present time. Spanish peanuts contain, according to Thompson and Bailey,[6] 52.5 per cent oil, and Vir-

ginias 43.3 per cent. On this basis, the trash being taken into consideration, a ton of unshelled Spanish peanuts produces about 700 pounds of oil; a ton of Virginias, 500 pounds. A by-product of peanut-oil manufacture is peanut meal; a ton of shelled peanuts produces 750 pounds of meal.

The peanut crop is also used to a large extent for feeding livestock. The tops of the plants may be cut for hay, and pods removed from the ground afterwards, or the crop may be pastured by hogs. The hay yield varies from 1 to 2 tons per acre and compares favorably in feeding value with good clover hay. Peanut straw, which is the herbage left after the pods have been removed, has a somewhat higher feeding value than peanut hay, but is not so bright or palatable. The use of the peanut crop for fattening hogs is important, especially in the Gulf Coast states.

CULTURE

Seed. The use of good seed of peanuts, as with other crops, is very important. The use of inferior seed has been the cause of many poor yields of peanuts. Seed should be selected from plants producing a large number of mature pods. The seed after harvesting should be cured and handled in such a manner as to retain their vitality. This result can be secured by proper stacking and storing in a dry place.

In the planting of the large-podded varieties, shelled peanuts are used, but, in the case of the Spanish varieties, the unshelled peanuts are planted. In many instances where peanuts are planted unshelled, they are soaked in cold water from 12 to 24 hours before planting and dried 1 or 2 hours after soaking. Shelled nuts should never be soaked before planting.

Time of Planting. Peanuts should not be planted until danger of frost is passed, and the soil is reasonably warm. If a good stand is to be assured the seeds should germinate promptly after being planted. The commercial crop is planted somewhat later than corn and beans. The earlier varieties, such as the Spanish, may be planted somewhat later than the later ripening varieties, such as the Virginia. Planting usually takes place from Apr. 10 in the Gulf Coast states to May 10 in the Virginia–North Carolina district. However, in the far South the early varieties may be planted as late as July 1 with fair results.

Rate of Planting. Small-podded varieties are usually seeded at the rates of 32 to 48 pounds of unshelled nuts, or 23 to 34 pounds of shelled nuts per acre, depending on the distance of planting.

Large-podded varieties are usually shelled before planting. The rate of planting varies from 38 to 45 pounds per acre.

The distance of planting varies with the tools used in cultivation, character of soil, and the variety of peanuts grown. The distance between rows varies from 2½ to 3½ feet. The Virginia runner and Jumbo varieties are usually seeded about 9 inches apart in the row; Virginia Bunch, 6 inches; and Spanish, 3 inches in the row.

Shellers for seed peanuts have been developed that will shell 300 pounds of nuts in 1 hour, or the amount one man can shell by hand in 300 hours.

Depth and Methods of Planting. The depth of planting varies with the soil. On light sandy soils the usual depth is from 1½ to 2 inches, while on heavier soils the depth varies from 1 to 1½ inches. On moist soil the depth suitable is less than on dry soil.

The planting is usually done by machines, although it is sometimes done by hand. However, the hand method is not so economical as machine planting when a commercial crop is grown.

Fertilization. The kind and quantity of commercial fertilizer that may be profitably used for peanuts depend almost entirely on the fertility and character of the soil. On thin, sandy soils and those not in a good state of fertility 300 to 500 pounds per acre of a complete fertilizer may, as a rule, be used to advantage (Beattie and Beattie[2]).

Peanut seed should never come in contact with fertilizer. Fertilizer-placement machinery may be used to place the fertilizer in bands 2 inches to the side and 2 inches below the seed. Good results have been secured by applying 0-12-12 or 2-12-12 on top of the row as the plants are emerging.

Soils adapted to peanut production are usually sandy in character and may be injured by overliming. The soil should be limed to maintain a pH of 5.7 to 6.2.

Colwell and others,[7] in North Carolina, recommend that at least 400 pounds of gypsum or land plaster be applied to the foliage at early blooming stage. They found that gypsum (calcium sulfate) produced about twice as high shelling percentage and yield per acre as did no treatment. The shelling percentage and yield per acre were lower than the no treatment where potassium sulfate and magnesium sulfate were used. They concluded, therefore, that calcium is the element responsible for the beneficial effects obtained from the use of gypsum on low-calcium soils. Thus it is essential that a supply of calcium be readily available to the calcium-hungry "peg," to enable proper development of nuts to take place.

Leaf Spot Control. Killinger and others[8] in Florida found that, during a 7-year period, sulfur applied to the peanut foliage for the control of leaf spot increased the yields of Florida Runner peanuts by an average of

33.8 per cent. During a 4-year period, a similar treatment increased the yield of Spanish peanuts by 35.2 per cent.

Cultivation. The crop requires cultivation similar to that recommended for corn, but hand hoeing is often necessary. Frequent cultivations should be given from the time the rows can be followed until the plants begin to form pods; often the first cultivation is done by harrowing diagonally across the rows just as the plants are appearing.

Time of Harvesting. The crop should be harvested before frost. The proper time for harvesting the crop may be recognized by a slight yellowing of the foliage and by an examination of the pods. If the pods have begun to shed at the base of the plant and if the inside of the shells has begun to color and show darkened veins, the crop is ready to harvest. The pods will not all mature at the same time, but harvesting should be done when the majority have reached maturity.

Methods of Digging. There are various ways of digging the crop. A common method is to remove the moldboard from the ordinary turn plow and run the share beneath the row of peanuts. Thus the tap roots are cut off and the plants loosened. The plants can then be removed with a fork and placed in bunches. The object of any implement is to cut off the roots and loosen the plants. The regular horse-powered potato diggers with elevators are also used with good results.

Reed[9] reports on a tractor-mounted peanut shaker that has been developed especially for harvesting peanuts. With it one man lifts, shakes, and windrows two rows of peanuts that have been loosened by blades on the tractor cultivator frame. The windrow is loose and can be stacked as easily as hand-piled peanuts or, if left, dries out rapidly so that in favorable weather the peanuts can be picked from the windrow in 5 to 8 days. A combine equipped for picking peanuts from the windrow or a picker arranged to do it will do this job in 3 man-hours per acre. As the stacking operation is eliminated, the man-hours required for harvesting an acre of peanuts can be reduced from 32.0 to 3.75.

Experiments are under way, with promising results, whereby peanuts are harvested in the usual way but are then dried in a heated drier instead of by the old method of stacking around poles.

Stacking. After digging, the plants are allowed to lie on the ground until the leaves are slightly wilted; wilting ordinarily requires about 3 or 4 hours.

The vines are then stacked around poles to which two crosspieces have been nailed a few inches above the ground. The poles are usually 7 feet long, 3 to 4 inches in diameter and sharpened at both ends. The crosspieces should be 14 to 18 inches long. It requires 15 to 30 poles for an acre of peanuts, according to the yield. The peanuts are stacked with

the nuts next to the pole and the branches out. The stacks should be made slender and tapering toward the top to aid in shedding water. Each stack is usually topped with grass or weeds to shed rain.

When the peanuts are intended for the market the curing process in the stacks requires about 6 weeks. If the crop is to be fed to livestock, it may be allowed to cure 2 to 4 weeks in the stacks; then it may be stored in barns or sheds.

Picking. Picking is usually done in the fall during the months of October, November, and December. The pods should be thoroughly cured and the vines dry and brittle. Most of the peanuts are picked by machinery at the present time, but formerly hand picking was the more common method. The machine picks about 250 bushels of peanuts per day on the average. To prevent discoloration and consequent reduction in market value the picked pods should be kept free from dampness.

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Topics for Discussion

1. How do peanuts differ from other legumes? Are they nuts or peas?

2. List some of the uses of the peanut other than as a confection for ballgames and circuses.

3. What are the climatic and soil limitations of the crop in the United States?

4. Does peanut-fed pork differ in any way from corn-fed pork, or is this an advertising myth?

CHAPTER XXV

SOYBEANS (Soja max)

The soybean is adapted mainly to temperate regions with fairly humid, warm growing seasons. In regions of tropical or subtropical climate, the plants often give good growth, but the pods rarely fill. The soybean is less sensitive to frost than corn or cowpeas and is less affected by drought or wet weather than these two crops.

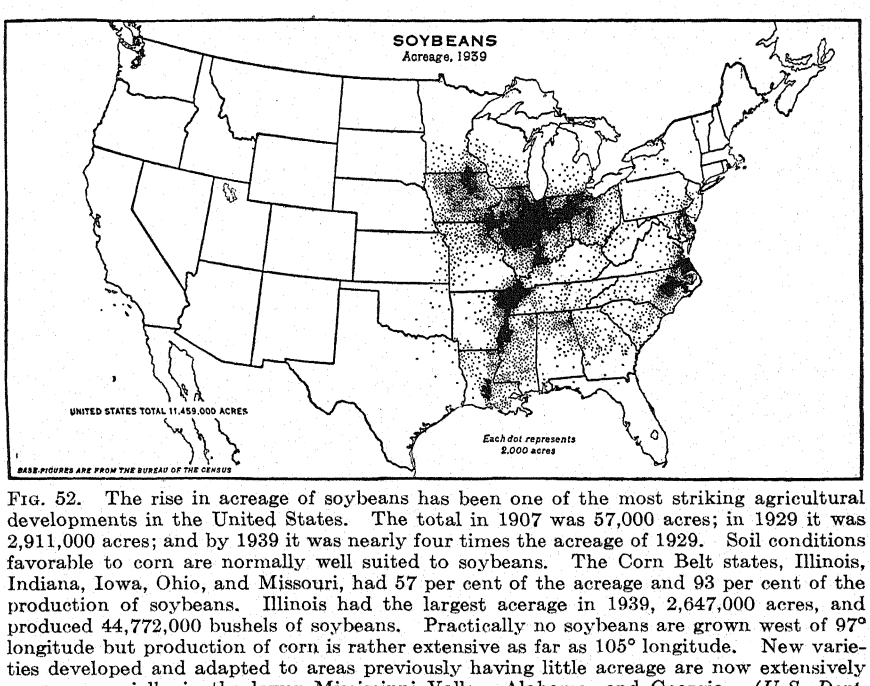

FIG. 52. The rise in acreage of soybeans has been one of the most striking agricultural developments in the United States. The total in 1907 was 57,000 acres; in 1929 it was 2,911,000 acres; and by 1939 it was nearly four times the acreage of 1929. Soil conditions favorable to corn are normally well suited to soybeans. The Corn Belt states, Illinois, Indiana, Iowa, Ohio, and Missouri, had 57 per cent of the acreage and 93 per cent of the production of soybeans. Illinois had the largest acerage in 1939, 2,647,000 acres, and produced 44,772,000 bushels of soybeans. Practically no soybeans are grown west of 97° longitude but production of corn is rather extensive as far as 105° longitude. New varieties developed and adapted to areas previously having little acreage are now extensively grown, especially in the lower Mississippi Valley, Alabama, and Georgia. (*U.S. Dept. Agr. Bur. Ag. Econ.*)

World Production. During the 10-year period 1930–1939,[1] China produced an average of 217,885,500 bushels of soybeans; Manchuria 159,432,500 bushels; and the United States, 36,385,000 bushels. Production figures for many countries are not available since the date listed above. However, in the United States the average production during

the 4-year period 1941–1944 was 169,682,500 bushels. In 1945 the production had increased to 191,722,000 bushels.

The soil requirement of the soybean is about the same as that of corn, provided inoculation is practiced, but on very poor soils it does not do so well as cowpeas. It does well on all kinds of soils but thrives best, other things being equal, on sandy or clay loams.

Production in the United States. The relative growth of the soybean crop in the United States may be shown by the following figures:[1] In 1929, 2,429,000 acres were grown for all purposes. The acreage increased to 5,764,000 in 1934, 9,565,000 in 1939, and 13,564,000 in 1944.

In 1920, North Carolina produced 65.9 per cent of the entire crop grown for seed, while in 1932 Illinois led by producing 47.5 per cent of the crop.

During the 10-year period 1933–1942, Illinois produced an average of 32,508,000 bushels of soybeans; Iowa, 10,093,000 bushels; Indiana, 9,479,000 bushels; and Ohio, 7,195,000 bushels. The total production in the United States was 68,771,000 bushels with an average acre yield of 17.1 bushels.

In 1944, Illinois produced 71,400,000 bushels; Iowa, 42,580,000 bushels; Indiana, 23,150,000 bushels; and Ohio, 22,457,000 bushels. The production in the United States during that year was 192,863,000 bushels with an average acre yield of 18.4 bushels.

Historical. The origin of the soybean is not known, as its cultivation is lost in antiquity. It has been cultivated in China and Japan for many centuries and certainly before the Christian Era.

The soybean is a native of eastern Asia, and the wild form, a slender twining vine, *Glycine ussuriensis*, occurs in China, Manchuria, and Korea. In the literature of 1804, the soybean is first mentioned as being grown in the United States. The Perry expedition brought back two varieties from Japan in 1854. Several other introductions were made, and in 1898 the U.S. Department of Agriculture made numerous additional introductions. The production of the crop has increased rapidly in recent years, and there is a probability that the soybean will become one of the leading farm crops of the United States.

Varieties and Their Distribution. There are over 2,500 varieties of soybeans. However, the seedsmen and growers in the United States handle only about 100 varieties. The considerations in the choice of varieties are yield, habit of growth, coarseness, color of seed, ability to hold leaves, propensity to shatter seed, length of growing season, disease resistance, and oil content. Therefore the determination of the best variety for a locality will depend on whether it is to be grown for seed, forage, green vegetable, dry edible, or for general purposes.

Classification and Varieties. Morse and Cartter[2] have classified soybeans as follows:

Very early (100 days or less):
- Seed . . . . Cayuga, Mandarin, Minsoy
- Forage . . . . Cayuga, Chernie, Ogemaw, Soysota, Wisconsin Black
- Green vegetable . . . . . . Agate, Sioux

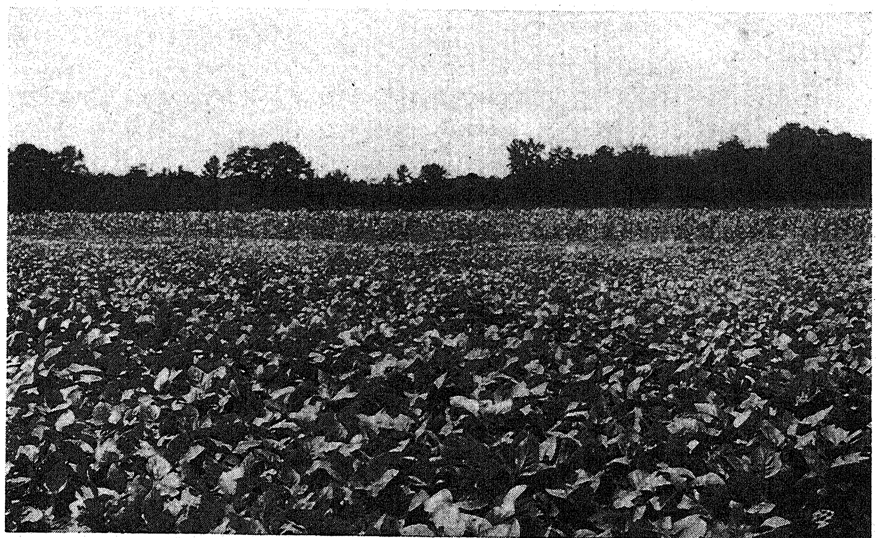

FIG. 53. Soybeans grown for hay in Shelby County, Alabama. (*U.S. Dept. Agr. photograph.*)

Early (101 to 110 days):
- Seed . . . . A.K., Aksarben, Dunfield, Elton, Habaro, Hoosier, Illini, Ito San, Manchu, Mandell, Mukden, Pinpu, Richland, Wea
- Forage . . . . A.K., Black Eyebrow, Chestnut
- Green vegetable . . . . . . Bansei, Chusei, Goku, Kanro, Waseda
- Dry edible . . . . Bansei, Chusei, Goku, Kanro, Waseda

Medium early (111 to 120 days):
- Seed . . . . Harbinsoy, Hongkong, Mansoy, Midwest, Scioto
- Forage . . . . Harbinsoy, Ilsoy, Medium Green
- Green vegetable . . . . . . Fuji, Hakote, Hiro, Hokkaido, Jogun, Kura, Osaya, Sato, Shiro, Sousei, Suru, Toku, Willomi
- Dry edible . . . . Hokkaido, Jogun, Osaya, Sousei, Suri, Toku, Willomi

Medium (121 to 130 days):
- Seed . . . . Hurrelbrink, Macoupin, Yokoten
- Forage . . . . Columbia, Ebony, Kingwa, Lexington, Norredo, Ozark, Peking, Pine Dell Perfection, Sooty, Virginia, Wilson, Wilson-Five

Green vegetable......Chame, Funk Delicious, Imperial
Dry edible...........Funk Delicious, Imperial

Medium late (131 to 140 days):
Seed.................Arksoy, Chiquita, Dixie, Easycook, Haberlandt, Herman, Hollybrook, Morse, Southern Prolific, Tokyo, Wood's Yellow
Forage...............Chiquita, George Washington, Laredo, Mammoth Brown, Old Dominion, Tarheel Black
Green vegetable......Aoda, Hahto, Higan, Rokusun
Dry edible...........Easycook, Haberlandt, Higan, Rokusun, Tokyo

Late (141 to 160 days):
Seed.................Clemson, Delsta, Hayseed, Mamloxi, Mammoth Yellow, Mamredo, Missoy
Forage...............Barchet, Clemson, Hayseed, Missoy, Pee Dee, Southern-green
Green vegetable......Nanda
Dry edible...........Nanda

Very late (161 or more days):
Seed.................Charlee, Creole, Delnoshat, Georgian, Monetta, Nanking, Palmetto, White Biloxi, Yelredo
Forage...............Avoyelles, Biloxi, Charlee, Creole, Georgian, Monetta, Oloxi, Otootan, Palmetto, Yelredo

According to Henson,[3] the development of adapted higher yielding soybeans for industrial use has been under way to meet the demand for more oil during the war. Varieties developed of particular importance to the South include an early type, S100; a midseason type, Ogden; and late types, Volstate, Roanoke, and CNS.

Composition. Piper and Morse[4] report that of the entire soybean plant 25.45 per cent is stems, 40.18 per cent leaves, and 34.37 per cent pods. The seed consists of cotyledons, 90 per cent; embryo, 2 per cent; and seed coat, 8 per cent. The composition of the different parts of the soybean plant at various stages of growth is shown in Table 18 taken from Piper and Morse.[4]

The composition of the different parts varies to a great degree as the plant approaches maturity.

Botanical. The soybean (*Soja max*) is a member of the family *Leguminosae*. The plant is an annual, determinate in growth; most varieties are erect and branch from a definitely defined main stem. The branches may be spreading or ascending, and short or elongated, as in the case of the lower branches. In some varieties there is a tendency to twine, and the plants are suberect to procumbent. However, the form of the plants is greatly modified by environmental influences.

There is a great variation in shape, size, color, and persistence of the leaves of the different varieties. In practically all varieties the leaves turn yellow as the pods ripen and fall off when the pods are mature.

TABLE 18. COMPOSITION OF THE DIFFERENT PARTS OF THE SOYBEAN PLANT AT DIFFERENT STAGES OF GROWTH, AT ARLINGTON FARM, VIRGINIA

	Moisture, per cent	Protein, per cent	Fat, per cent	N-free extract, per cent	Fiber, per cent	Ash, per cent
Roots:						
Full bloom	5.33	9.31	0.76	32.66	45.76	6.18
Pods ½ grown	5.21	8.76	0.93	32.88	46.85	5.38
Plants mature	4.91	3.59	0.56	27.00	59.09	4.85
Stems:						
Full bloom	4.72	10.44	0.56	35.43	43.31	5.54
Seed ½ grown	3.82	12.34	0.45	34.97	43.67	4.75
Plants mature	4.84	3.33	0.67	30.86	57.72	2.58
Leaves:						
Full bloom	5.72	19.56	2.08	49.85	14.65	8.14
Seed ½ grown	6.04	19.56	2.61	47.06	14.87	9.86
Pods:						
Seed ½ grown	5.57	18.53	1.50	41.03	25.31	8.06
Plants mature	6.53	5.26	1.40	45.01	35.61	6.19
Seed:						
Seed ½ mature	5.84	37.38	12.02	30.45	8.07	6.24
Plants mature	5.36	37.56	18.61	29.28	4.64	4.55

However, some varieties possess green leaves even when nearly all the pods are mature.

Inflorescence. The flowers are borne on short axillary or terminal racemes, and there are usually eight to sixteen flowers in a cluster. The flowers, which are white or purple, are nearly always without odor.

The flowers are normally self-pollinated and completely self-fertile. The different varieties cross readily, and it is estimated that the amount of natural cross-pollination is but 1 to 2 per cent. The amount of natural crossing would probably be greater were it not for the fact that the pollen is shed about the same time the flowers open.

Uses. The soybean has a great diversity of uses. In the Orient the crop is grown mainly for seed, which is used for human consumption and for the manufacture of food products. In this country the crop is grown largely for forage, green manuring, and the production of seed for the soybean-oil industry.

Oil. In the manufacture of oil from soybeans, by the expeller process, 1 ton of beans will yield on the average 32 gallons of oil (about 7.5 pounds to the gallon) and 1,600 pounds of cake. The difference of 130 pounds represents loss due to cleaning and loss of moisture. However, the percentage of oil will vary. The soybean meal made by grinding the cake contains 44.65 per cent protein, 8.77 per cent fat, 27.12 per cent nitrogen-free extract, 5.89 per cent ash and 5.96 per cent fiber.

Hay. The value of soybeans for hay is indicated by their analyses. The percentage of protein, on the average, is 11.7 per cent; carbohydrates, 39.2 per cent; and fat, 1.2 per cent. The straw analyses show 2.8 per cent protein; 38.5 per cent carbohydrates; and 1 per cent fat.

Silage. Piper and Morse[4] give the average analysis of soybean silage as 72.68 per cent water; 3.93 per cent protein; 9.02 per cent carbohydrates; 2.44 per cent fat; 3.51 per cent ash; and 8.32 per cent fiber.

Soybeans, in addition to being suitable for hay and silage purposes, have a useful place as a pasturage or soiling crop.

CULTURE

Seeds. Care should be used in choice of the variety, since great differences frequently exist. Varieties suitable for the purpose for which they are desired should be chosen, and they should be adapted to the conditions under which they are to be grown.

Since soybean seeds lose their vitality rapidly, one should not sow seed 2 years old without first determining their germination. Farmers should use care in curing and storing soybean seeds, since these seeds are easily injured, and their viability will be readily destroyed if they are not properly handled.

Time of Seeding. The soybean crop should not be seeded until danger of frost is over. Early-seeded crops of soybeans are generally seeded 1 to 2 weeks after early-planted corn. The plants grow very slowly when the ground is cold, and therefore extremely early seedings are inadvisable. However, when seeded too late, the crop may not mature before frost in the fall. Soybeans for grain or the main hay crop will give the highest yields when seeded about corn-planting time. The crop may be seeded for pasturage, green manure, soiling, or for hay as late as Aug. 1 in the South and July 1 in the North. Soybeans seeded early in the planting season yield much higher than those seeded late.

Rate of Seeding. The rate of seeding depends on the size of seed, the purpose for which the crop is grown, and the method of seeding. When the crop is seeded in rows from 2 to 3 feet apart, the usual rate of seeding is approximately 20 to 30 pounds per acre. In the case of broadcast seeding, the usual rate is 1 to 1½ bushels per acre. In Iowa,

however, Hughes and Wilkins[5] found that twice the rate ordinarily recommended gave the highest yields of both hay and seed. When the seeds were spaced 1 inch apart in cultivated rows, the most profitable yields were secured.

When corn and soybeans are grown together, the most desirable rate of seeding is to have two corn plants and from two to four soybean plants per hill. If the crop is drilled, one corn plant every 12 to 16 inches and one soybean plant every 6 to 8 inches in the row is recommended.

Depth of Seeding. The depth of seeding is of special importance in the case of soybeans, since poor stands are often the result of seeding too deeply, especially on soils that have a tendency to form a crust on the surface. As a rule, on the heavier types of soil, the depth of seeding should not exceed 2 inches, but in sandy soils the planting may be as deep as 2 to 4 inches.

Inoculation. The soybean, in common with other legumes, utilizes the nitrogen of the atmosphere through the bacteria that live in the nodules on the roots. Soybeans are inoculated only with the bacteria from soybean nodules. Therefore, care should be used to make sure that the plants become inoculated by artificial means, if natural inoculation is not to be had. Experimental results show that inoculated plants as a rule contain more protein and produce more dry matter than uninoculated plants.

Fertilization. Sears[6] states that a 20-bushel crop of soybeans harvested from the field with the straw returned, removed slightly more phosphorus than a 40-bushel crop of corn, of which only the grain left the field. At the same time, the soybeans removed more than three times as much potassium as did corn. A 2½-ton soybean hay crop removed twice as much phosphorus and five times as much potassium from the soil as did a 40-bushel crop of corn. Thus it may be seen that it is highly important to furnish plant nutrients to the crop when they are deficient in the soil.

Methods of Seeding. The grain drill is probably the best machine with which to seed soybeans, either in rows or broadcast. If some of the openings in the feed box of the drill are stopped, the width of rows can be regulated. Corn planters and cotton planters are often used to seed soybeans when they are seeded in cultivated rows.

With the development of machinery adapted to soybean production, there has been a marked change in methods of planting during the past few years, especially in the Corn Belt. Experience shows that factors favoring the seeding of soybeans in rows are higher yields of seed and hay, larger beans, more uniform stand, higher percentage of foliage, less lodging, lower seed requirements in planting, and less chance of poor

results in the case of inexperienced growers. Drilling in close rows, however, has some important advantages, such as producing a finer quality of hay, eliminating the need for special machinery, and decreasing the cost of production (Morse and Cartter[2]).

For seed production, seeding in rows is usually preferable to broadcasting with the drill. In many regions of the Corn Belt, however, the latter method gives higher yields. This is shown by the results reported by Hughes and Wilkins[5] in Iowa. Seeding in rows will make necessary several cultivations of the crop, but this cost will usually be balanced by the difference in cost of seed. The cultivation will also destroy the weeds. When the crop is to be used for hay, for soiling, or for green-manure purposes, and when a fine quality of forage is desired, broadcasting the seeds with a grain drill is advisable where the land is comparatively free from weeds.

The spacing of rows depends upon the variety and productiveness of the land. As a rule, the spacing is from 2 to 3 feet.

When soybeans are seeded with corn, various methods of seeding are used. The beans may be seeded in the same hill with the corn, in the same row with the corn but in alternate hills, in alternate rows with corn, with two rows of corn and two rows of soybeans alternating, or seeded broadcast in the corn at the last cultivation. The latter is a common practice in the Southern states. The corn may be checked and the soybeans either checked with the corn or drilled, or both the corn and soybeans may be drilled.

Cultivation. Soybeans are sometimes slow in appearing above the surface of the ground when a crust forms on it after the crop is planted. This is especially true in case of soils that tend to run together. In such cases it is advisable to break the crust by the use of a weeder, spike-tooth harrow, or rotary hoe. These implements may be used profitably for cultivating the crop at intervals until the plants are from 8 to 10 inches tall, regardless of whether they are in rows or have been broadcast with a grain drill. Later cultivations of soybeans in rows may be given with the same implements used for cultivating corn. Soybeans should not be cultivated when they are wet with dew or rain, as they break very easily.

Time of Cutting for Hay. It is best to cut hay when the pods are well formed. If the crop is cut earlier, the yield is less, and the crop is more difficult to cure but the percentage of protein is higher than when cut later. When the crop is allowed to stand too long, there is a loss of leaves, the stems become more fibrous, and the feeding value is less.

Curing Soybean Hay. Since soybeans have rather coarse stems that dry slowly as compared with the leaves, a somewhat different method of curing must be used than commonly followed for ordinary

hays. However, soybean hay is more easily cured and handled than cowpea hay. The plants should be allowed to remain in the swath until the leaves have thoroughly wilted but not until they become dry and brittle. The hay should then be raked into windrows and left there 2 or 3 days, according to the kind of weather; it should then be placed in small cocks or shocks. Under favorable curing conditions it usually requires 5 or 6 days to cure soybean hay in good condition.

The curing process can be facilitated by the use of curing frames or poles with crosspieces near the bottom. The frames are usually three- or four-sided pyramids consisting of boards or poles 3 to 6 feet long, fastened together at the top and held by crosspieces near the bottom. The hay is thus held off the ground. In this way the circulation of air is aided, and curing is more rapid.

Soybeans will yield from 1 to 3 tons of hay to the acre, and occasionally 4 to 5, depending upon the fertility of the soil and the season. Good forage varieties under favorable conditions should average at least 2 tons to the acre (Morse[7]).

Time of Cutting for Seed. Since some varieties of soybeans shatter their seeds rather badly when mature, attention should be given to avoid this loss. As a rule, the leaves of the soybean plants turn yellow and drop off by the time the pods are mature. In case the bean harvester or combine is not used, it is best to cut when nearly all the leaves have fallen and practically all the pods have turned in color. When the harvesters or combines are used, the crop should be allowed to reach maturity.

Rather[8] states that one of the major factors in the great increase in soybean acreage in the United States is the use of the combine to harvest the crop. This is not merely a matter of cost, although the harvest of soybeans with the combine costs only about one-half as much as by the binder-and-thresher method; it is also a matter of timeliness and convenience. The combine harvest of soybeans extends over a long late-fall period. In general, the beans stand well and shatter but little. Combines have been designed to cut close to the ground, and losses incurred with this method of harvest have become relatively insignificant. Probably the first consideration is to delay the start of harvest until the beans are down to 14 per cent moisture to ensure their safety from heating and spoilage.

The best producing varieties of soybeans, when grown alone for beans under proper culture and favorable conditions, yield from 25 to 40 bushels to the acre. Yields, however, in different sections range from 15 to 25 bushels in the Northern and Central states and from 15 to 35 or more bushels in the Southern states. Maximum yields of 50 or more bushels to the acre have been reported from North Carolina and Tennessee (Morse[7]).

The average yield for the United States has been only 17 to 18 bushels during the past decade.

Methods of Harvesting Seed. There are several ways by which the seed may be harvested. The ordinary mowing machine with a side-delivery attachment, the self-rake reaper, and the grain binder are sometimes used to harvest the crop. When cut, the plants are put into small piles or shocks for several days and are then threshed with the ordinary threshing machine. In this process the speed of the cylinder is reduced about one-half, and some of the spikes in the concaves are removed; the speed of the fan and of the other parts of the separator, however, is maintained. However, unless the threshing is done by an experienced person, many cracked beans are likely to be obtained. The beans may also be removed from the vines by the use of a flail.

There are on the market at the present time several types of special bean harvesters, which usually give good results, since they save labor and time, although the loss of beans is not entirely eliminated. The combine is used with success in harvesting soybeans for seed. The speed of the cylinder and separator should be controlled as suggested for the threshing machine.

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Topics for Discussion

1. How do you account for the rapid expansion of soybean production in the Corn Belt?

2. Compare cowpeas and soybeans as to yield, soil-improving qualities, and adaptability for your section.

3. Discuss soybeans as a food crop. Is it likely that this crop will supersede field beans as a cheap high-protein food?

4. How much is the soil improved by growing a seed or hay crop of soybeans and removing this from the land?

5. Will a soybean crop that has no nodules on the roots remove more or less nitrogen from the soil than a corn crop?

CHAPTER XXVI

COWPEAS, FIELD PEAS, AND FIELD BEANS

COWPEAS (Vigna sinensis)

The cowpea is grown most extensively in the Southern states. It is a warm-weather plant and is injured by slight frost. Cowpeas will stand considerable drought and a moderate amount of shade. The crop succeeds on nearly all kinds of soils. It is apparently better adapted to more kinds of soils and will make better growth under adverse conditions than most of the other legumes.

During the 10-year period 1933–1942,[1] the average acreage of cowpeas grown in the United States was 4,864,000; in 1943 the acreage was 3,466,000; and in 1944 the acreage was 2,546,000. During the same period, the production amounted to 6,932,000, 4,854,000, and 4,213,000 bushels, respectively.

During the 12-year period 1933–1944,[1] Texas produced an average of 1,115,000 bushels; South Carolina, 993,000 bushels; and Georgia 983,000 bushels. During those years the average yield in the United States was 5.3 bushels per acre.

Historical. The cowpea is a native of central Africa. There the wild plant, which differs very little from the cultivated cowpea and with which it readily crosses, is widely diffused. The crop seems to have been cultivated since an early period. It was introduced into China in prehistoric times and was known in Europe at least as early as the Christian Era. It seems to have come to the United States at least as early as the latter part of the eighteenth century.

Classification. The characteristics of the cowpeas vary greatly. As a rule, the plants are indeterminate in growth; *i.e.*, they continue to grow until killed by frost. These plants have long, trailing vines. The following classification will serve to show certain characteristics that may be used in distinguishing some varieties.

1. *Habit of Growth.* Prostrate; procumbent; low, half-bushy; tall, half-bushy; and treelike or erect.
2. *Color of Seeds.* Dominant colors: black, white, and red.
    - *a.* Uniform in color or pattern.
    - *b.* Not uniform in color or pattern.
        - (1) Spotted.
        - (2) Marbled, as Whippoorwill.

(3) Speckled, as Taylor and New Era.
(4) Marbled and speckled, as Groit.

3. *Shape of Seeds and Pods.* The shape of seed falls into five main divisions: reniform or kidney-shaped, subreniform, oblong, rhomboid, and globose. The shape of the seed is closely related to that of the pod. The kidney-shaped seeds, which are the most common, develop in the pod separate from each other. The "crowder" or globose seeds are produced in long, slender pods and are crowded closely together when developing; hence the name.

In shape, most of the pods are curved; in some varieties, however, the pods are straight, and in a few cases they are coiled into one or two complete turns. With most varieties the pods are constricted between the seeds, but in the case of some varieties this characteristic does not occur, as the pods are terete.

4. *Color of flowers.*

a. White or nearly white. This color is usually associated with white or partly white seeds.
b. Pale violet or purple.

5. *Time of ripening.*

a. Early, those maturing in from 70 to 80 days.
b. Medium, those maturing in from 90 to 100 days.
c. Late, those that require more than 100 days in which to mature.

Value of Varieties. The cowpea is grown for two main purposes: forage and seed. The yields vary with the variety and conditions of climate, soil, and culture.

There are about fifteen varieties of cowpeas in common cultivation, with a large number grown in a small way. The most valuable American varieties of cowpeas for forage are the Whippoorwill, Iron, and New Era, and their hybrids, the Brabham and Groit.

Uses. The cowpea is used to a rather large extent in the Southern states for human consumption. Cowpeas are commonly used in three forms: in the pod, shelled green, and shelled dried. According to Langworthy and Hunt[2] the green shelled cowpeas contain 9.4 per cent protein, 0.5 per cent fat, 23 per cent carbohydrates, and 1.4 per cent ash; moreover, they have a food value of 620 calories per pound. The dried cowpeas have 21.4 per cent protein, 1.4 per cent fat, 60.8 per cent carbohydrates, 3.4 per cent ash, and a food value of 1,590 calories per pound.

As has been discussed by Morse,[3] cowpeas make an excellent hay when properly handled. The hay analyzes, on the average, 16.1 per cent protein, 40.3 per cent carbohydrates, 3.2 per cent fat, 10.2 per cent ash,

and 19.8 per cent fiber. The crop is used to some extent as pasturage, especially for hogs. It is also used for silage purposes, especially for mixing with corn or sorghum, and it serves a very useful purpose as a green manure. The tops contain 1.96 per cent nitrogen, 0.51 per cent phosphoric acid, and 1.93 per cent potash. The roots contain 1.18 per cent nitrogen, 0.55 per cent phosphoric acid, and 0.93 per cent potash.

CULTURE

Time of Seeding. Since the cowpea is injured by frost, it should not be seeded until danger of frost is over. After this danger is passed, the time of seeding depends largely on the purpose for which the crop is to be used. If seeded for hay or seed, the crop should be seeded early, but, for green-manuring and pasture purposes, the crop may be seeded late with good results ensuing.

Rate of Seeding. The rate of seeding will vary with the method of seeding. When the seeds are seeded in rows 24 to 40 inches apart, the rate of seeding is usually about 30 to 40 pounds per acre. In broadcast seeding the usual rate of about 90 pounds to the acre is followed.

Method of Seeding. The cowpea crop is ordinarily sown in one of three ways: broadcast, in rows, and in mixture with other plants such as sorghum, Sudan grass, corn, etc. The method used will depend largely on the purpose for which the crop is seeded. In case the crop is desired for forage or green manuring, the broadcast method is generally used, but for seed production the crop is generally seeded in rows. The rows are usually 2½ to 3 feet apart, and the plants should stand 2 to 3 inches apart in the row. For hogging-off or for silage purposes, cowpeas are frequently seeded with corn, either at the time the corn is planted or at the last cultivation of the corn crop. They are also used for seeding with sorghum, Johnson grass, Sudan grass, millet, and soybeans.

Cultivation. If the crop is seeded in rows, two or more cultivations are necessary to secure satisfactory yields. The ordinary corn-cultivating implements may be used and cultivation should cease about the time the plants began to bloom.

Harvesting. If the crop is harvested, it is usually for one of two purposes, hay or seed. The crop ripens unevenly and it is sometimes difficult to determine the proper stage for harvesting. Usually blossoms and green and ripe pods occur on the vines at the same time. However, as a rule, the crop is cut for seed when one-half to two-thirds of the pods are ripe. There are various methods of harvesting, such as by hand, by special harvesters, and by self-rake reapers.

When cut for hay the crop should be cut when most of the pods are fully developed and when the first ones have ripened. If cut much before

this time, the hay is difficult to cure, and, if the crop is harvested much later, there will be some loss due to shattering of seed and leaves and to the long and woody stems. The ordinary mowing machine is commonly used for harvesting cowpeas for hay.

FIELD PEAS (Pisum arvense)

Origin and History. The field pea is native to the Mediterranean region of southern Europe and to northern Africa; it is also grown eastward through Syria and Palestine to the Himalaya Mountains. The cultivation of this crop is very ancient, as seeds have been found among the remains of lake dwellings in Switzerland. The field pea was brought into the United States at an early date, as there are records of its having been grown in Virginia as early as 1636.

Production. The area devoted to field peas has increased in the United States from 250,000 acres in 1929 to 727,000 acres in 1944.[1] During that period, the production increased from 1,795,000 bags (100 pounds per bag) to 8,873,000 bags.

During the 12-year period 1933–1944, Washington produced an average of 2,216,000 bags of field peas; Idaho, 1,244,000 bags; Montana, 325,000 bags; and Oregon, 202,000 bags.

Description. The field pea is an annual with slender, hollow stems, 1½ to 10 feet long, that stand erect only when there are plants from which they can secure support. The plants often have one or two stalks but seldom more than three, and the entire herbage is pale green with a whitish bloom on the surface. Each leaf has one to three pairs of leaflets and is terminated by one or more pairs of slender, branched tendrils by which the plant fastens itself to supports. The flowers are reddish purple, parti-colored, or white, and usually two or three are borne by each flower stalk. The hanging pods, which are green, or less often yellow, are about 3 inches long and contain five to nine nearly round seeds.

The garden pea and the field pea resemble each other very closely since they belong to the same species. As a rule, the varieties with rounded yellowish or greenish seeds and white flowers are classed as field peas. In some cases the field-pea varieties have yellow seeds and white flowers; in other cases the flowers are colored, and the seeds are brown to black, marbled, mottled, or speckled. There are all possible intergrades, and frequently the same variety is used for garden and field purposes.

Adaptation. The field pea requires a cool growing season, high temperatures being more injurious than frosts. The climatic requirements of the field pea limit its successful production as a summer crop to the Northern states and Canada and to the mountainous sections of the Western states. In the South it is grown as a winter crop. Rainfall is less important than temperature. In western Canada, 15 inches of rain-

fall will allow the production of a good crop, while a rainfall of 20 inches is not sufficient in Kansas, Nebraska, and Colorado.

A well-drained soil is necessary for the successful production of the field pea, and it thrives best on a rich, calcareous soil. If the soil is very rich, the production of vines is great while the production of seed is small; on a poor soil the yield of both vines and seed is low.

Culture. The Golden Vine is the best general-purpose variety of the field pea; it is also the most widely grown variety. Among other varieties are the French June, Marrowfat, Prussian Blue, and Wisconsin Blue.

When the field pea is to be grown as a summer crop, seeding should be done so that the pods will be set before warm weather arrives. In southern Canada and in the northern tier of states in the United States, seeding usually takes place from April 1 to May 1; in the Intermountain Region, crops are usually seeded from April 1 to 15; and in the Southern and Pacific Coast states, where the crop is grown during the winter, the crop is seeded in the fall or early winter.

Under irrigation and in humid regions the rate of seeding varies from 1½ to 2 bushels for the small-seeded varieties like the Golden Vine, to 3 to 3½ bushels for the large-seeded varieties like the Marrowfat. Under dry conditions the rate of seeding is reduced about ½ bushel for each group. When a mixture of oats and field peas is used and seeded under conditions of abundant moisture, the field peas are sown at the rate of 1 bushel per acre and the oats at the rate of 1½ to 2 bushels. Under dry conditions this rate of seeding should be reversed. Field peas and oats require about the same conditions; the latter, however, will withstand more cold, and a mixture of field peas and oats is one of the oldest mixtures of a legume and a nonlegume.

The crop is generally drilled or sown broadcast, but the former method is to be recommended. In seeding the crop, one should see that inoculation is supplied, since field peas, like other legumes, thrive best only when inoculated.

Harvesting. The period of growth is approximately 60 to 100 days for hay, and 80 to 120 days for seed production. The crop should be cut for hay when most of the pods are well formed, and for seed when the pods are mature and the seeds are firm. When the peas are seeded with grain, the time of cutting may be determined by the ripeness of the grain; but as far as practicable, varieties of each that mature at the same time should be used.

Uses. The seeds of the field pea are used both as human food and as feed for domestic animals. The plants also make an excellent hay, especially when grown with a grain crop such as oats. The crop is grown more extensively for seed than for hay. In addition to these uses, field peas are valuable as pasturage and as a green-manure and cover crop.

FIELD BEANS (Phaseolus vulgaris)

During the 12-year period 1933–1944,[1] the average acreage in the United States devoted to the growing of field beans was 2,066,750. During the same period, Michigan produced an average of 4,448,250 bags of 100 pounds each; California, 4,476,000 bags; Idaho, 1,733,500 bags; and Colorado, 1,582,750 bags. The average production in the United States during those years was 15,692,500 bags. The acreage of field beans is shown in Fig. 49.

Varieties of Field Beans. Data from Rather[4] indicate that during the period from 1929 through 1938, the percentage of the Pea (navy) variety grown in the United States was 31.5; Pintos, 13.7; Great Northern, 12.2; and Lima, 8.4.

Planting. Field beans should not be planted until the seedbed is warm. They are usually planted in drill rows about 1 yard apart. From 2 to 3 pecks of seed per acre are required for planting, depending on the variety used. Careful and thorough cultivation is required for the beans.

Harvest. Bean-harvest machinery is designed to avoid much movement or shaking of the bean vines in order to prevent shattering. The cutter, or puller, consists of two broad blades set in a wheeled frame at a 60-degree angle to cut under two adjacent rows about 2 inches below the ground. Prongs pull the rows together into one windrow. The simplest harvest procedure then, if weather conditions permit, is to rake two of the windrows together with a side-delivery rake and thresh the beans from the windrow with a combine. Where wet weather at harvest time is common, a far safer procedure is to fork the pulled beans into field stacks about 4 feet in diameter and 2 feet high, built around a stake set firmly in the ground (Rather[4]).

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Topics for Discussion

1. Show where most of these crops are grown and discuss their importance for your section.

2. Why are field beans one of our most important high-protein foods?

3. Are cowpeas peas or beans?

4. Why do people in the southeastern section of the United States prefer cowpeas to field beans as a food crop, whereas the reverse is true in most other sections?

SECTION IV

FORAGE CROPS

CHAPTER XXVII

PASTURE AND HAY GRASSES

According to Piper,[1] there are about 6,000 species of grasses in the world. Of these only approximately sixty are of importance in cultivation, and not over twenty wild species are abundant or valuable in any one section. The discussion in this chapter will be limited to a few of the more important species.

TIMOTHY (Phleum pratense)

Origin and History. Although timothy was first cultivated in the United States, it is a native of the Old World. The name timothy comes from Timothy Hansen, who in about 1720 introduced the grass into Maryland. The name "Herd's grass" was given this plant because it was found growing in New Hampshire in 1700 by John Herd. The fact that the name "Herd's grass" still persists in the New England states causes some confusion, as redtop is called "Herd's grass" in a few localities in the South. Timothy is by far the most important hay grass in the United States.

Description. Timothy is the best known grass in this country and belongs to a species in which there are eleven closely related forms, one of which is the mountain timothy (*Phleum alpinum*). The plant is a perennial, semibunch grass. Timothy is primarily a hay plant and does not stand grazing well; however, when there is considerable aftermath produced, the crop may be grazed profitably.

Timothy differs from most other grasses in that the lower internodes, sometimes one and sometimes two, are often enlarged and referred to as "bulbs" or "corms." These bulbs or corms are in reality only thickened internodes. The corms are of annual duration forming in early summer and dying the next year when the plants mature. Oakley and Evans[2] have shown that in some instances timothy at times produces stolons,

and frequently there are two types of underground rooting stems. They describe the latter as follows:

> One type develops when the shoot that produces the new plant is covered with soil early in its growth. Some of the unelongated internodes connecting the shoot with the parent plant elongate, thereby pushing the shoot to the surface of the soil. Roots grow from the nodes between the elongated internodes.
>
> A second type of underground rooting stem is produced when timothy plants with growing culms are covered with soil. Buds that sometimes form on the culms of these plants frequently develop into shoots and ultimately into independent plants. The culms then become underground rooting stems.

Adaptation. Most of the timothy crop is produced in the northern half of the country east of the Missouri River.

Timothy is a northern grass and is adapted to a cool, humid climate. It does not do well in the United States south of latitude 36° North except at high altitudes. It will not thrive under hot, humid summer conditions, and under such conditions weeds, such as crab grass, compete with it strongly.

The crop is best adapted to the heavier soils, such as clays and loams, and will not thrive on dry or sandy soil regardless of its productivity. On the other hand, timothy thrives best where moisture is abundant, and under such conditions stands may be often obtained with little attention to the preparation of the seedbed. Timothy is now being grown under irrigation.

Uses. The importance of timothy as a hay crop is shown by the fact that the extent of this crop is four times that of all other hay grasses combined and equals all other hay plants, including clover and alfalfa. It is grown to a large extent with clover for hay.

REDTOP (Agrostis alba)

Origin and History. In some sections of Pennsylvania and the Southern states redtop is called "Herd's grass," which is the name given to timothy in the New England states. Redtop is not a native of the United States, and the first record of its cultivation in this country was in 1807. It is said to have been grown in France in 1761. Redtop is a native of the Old World and is found over most of Europe, Asia, in the western parts of Africa, and in Abyssinia.

Description. Of the many grasses belonging to the genus *Agrostis*, redtop is the only one that is of much importance as a hay plant. It is a perennial grass, with a creeping habit of growth, being stoloniferous, and it makes a coarse, loose turf. The rootstocks are shallow, vigorous, and about 2 to 6 inches long. The stems are frequently decumbent at the

base, and the nodes root freely. Redtop matures about with timothy and is frequently sown in mixtures with the latter grass. The panicles, which are reddish in color and loosely pyramidal in shape, are very characteristic.

Adaptation. Probably no cultivated grass has wider adaptation to both climate and soil than redtop. It will thrive in all parts of the United States with exception of the drier areas and the extreme South. It is found growing, however, from Canada to the Gulf of Mexico and from New York to California.

Redtop is at least as cold resistant as timothy and withstands summer heat to a much greater degree. It is not adapted to growing in shade and is but rarely found under such conditions.

The crop apparently shows but little preference as to soil type so long as plenty of moisture is present; but the heavier soils allow more luxuriant growth. Redtop thrives best on moist or wet soils, but in the face of this fact the plant can endure much drought and on poor uplands will do better than most grasses. Not only is redtop tolerant of acid soils but in fact seems to thrive better where lime is deficient.

Uses. The main uses of redtop are (1) a hay crop on wet or sour lands; (2) a part of pasture mixtures under humid conditions, especially on the nonlimestone soils; (3) a soil binder; and (4) an ingredient in hay mixtures that are to be fed on the farm.

BENT GRASSES (Agrostis spp.)

In addition to redtop (*Agrostis alba*) there are two other important cultivated species of the genus *Agrostis;* the two bent grasses, Rhode Island Bent (*Agrostis vulgaris*) and Creeping Bent (*Agrostis stolonifera*), both natives of Europe. These two grasses resemble redtop but differ from the latter in being much smaller and in having more stoloniferous root systems. They have approximately the same climatic and soil adaptations as redtop and are used for lawns and for putting greens on golf links, since they stand very close mowing. These grasses are of special importance on those soils where bluegrass does not thrive.

ORCHARD GRASS (Dactylis glomerata)

Origin and History. Orchard grass, the cock's-foot grass of England, is a native of the Old World. It is native to most of Europe, nearly all of the northern half of Asia, the mountains of Algeria, and the Canaries. It was cultivated in Virginia before 1760 and in this year was introduced into England. In Europe its cultivation began in the early part of the nineteenth century. It is now cultivated in practically all temperate regions.

Description. Orchard grass is a long-lived perennial grass that forms dense circular bunches. It does not produce good sod, being a typical bunch grass, and it has no stolons. The name "cock's foot" comes from the characteristic shape of the inflorescence. The folded leaf blades and compressed sheaths are also characteristic.

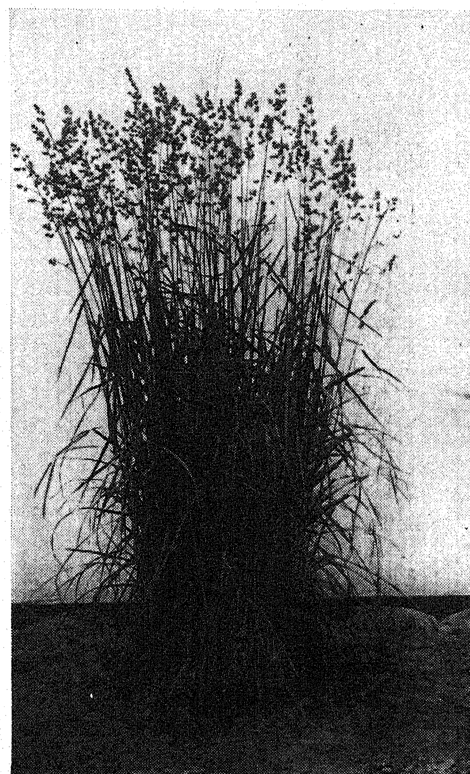

FIG. 54. A typical clump of orchard grass. (*H.M. McVickar, National Fertilizer Association.*)

The bunching habit of growth and the tendency for the stems to become woody soon after the blooming stage is reached may be considered objectionable features of orchard grass.

Adaptation. Orchard grass is grown to some extent in practically every state in the Union, but it reaches the greatest importance in Kentucky, southern Indiana, Tennessee, North Carolina, Virginia, West Virginia, and Maryland.

The crop is strictly adapted to temperate regions, but it will stand more heat than timothy and is more injured by cold. It starts growth earlier in the spring than most grasses, and this early growth may account

for some of the cold injury in the spring. Orchard grass is peculiarly well adapted for growing under shade; hence its name.

Orchard grass will grow on almost all kinds of soils, but it thrives best on the heavier soils such as clays and clay loams. It requires somewhat more moisture than timothy for best growth, but it will also make better growth during droughts than timothy.

Uses. Orchard grass is used for both hay and pasture. It will produce a fair amount of hay on the thinner, dry uplands, but the crop is woody if it is not cut at the proper time. It is used as a hay plant largely where timothy does not thrive. As a pasture grass, orchard grass serves an excellent purpose, especially in mixtures, since the growth begins early in the spring and since a large amount of aftermath is ordinarily produced. The other plants in the mixture tend to thicken the sod between the bunches of orchard grass.

KENTUCKY BLUEGRASS (Poa pratensis)

Origin and History. Kentucky bluegrass, also known as "June grass," is not a native of North America but occurs over nearly all Europe and the northern half of Asia and in the mountains of Algeria and Morocco. The first mention of it in the United States was made by William Penn in 1685. The grass has spread rapidly in certain regions in this country.

Description. Kentucky bluegrass is a perennial having creeping underground stems that bear tufts at the tips. It spreads rapidly by means of the rhizomes and forms a permanent sod. The panicles are spreading as compared with Canada bluegrass and purplish in color, and the stems are rather fine and cylindrical. The leaves are green and V-shaped in cross sections; the leaf tips resemble the bow of a boat in shape. Kentucky bluegrass should always be seeded in mixtures containing plants that reach full development fairly early, as bluegrass usually requires 2 or 3 years before a good dense sod is secured.

Adaptation. Kentucky bluegrass thrives best in the cooler sections of the countries. It can be grown farther south than timothy but it is not adapted to the Gulf states. It is the best known grass in America, with the probable exception of timothy.

Kentucky bluegrass is adapted to temperate regions of relatively high humidity but under irrigation it will grow under arid conditions. It is very cold resistant and will start growth during the warmer periods in the winter season. It makes an excellent early spring and fall growth but during the latter part of the summer the plants languish, even when moisture is abundant. However, if sufficient moisture is present, the

growth quickly revives in the fall. The crop grows only fairly well under shade.

Kentucky bluegrass thrives best in the well-drained heavier types of soil, rich in organic matter and plant nutrients. It was once thought that, on account of the lime present, this grass was especially adapted for limestone regions. However, the present indications are that the excellent growth in such regions is rather a result of the general richness of the soil than of the lime content. The grass is not so well adapted to dry or wet soils as redtop.

Uses. The main use of Kentucky bluegrass is for pastures and lawns. Most of the bluegrass pastures have arisen spontaneously, but they can be secured much quicker by sowing bluegrass seed in the mixture. The beauty of bluegrass lawns is well known.

CANADA BLUEGRASS (Poa compressa)

Origin and History. Canada bluegrass was introduced at an early date into the United States from Europe. It was found by Michaux in Quebec about 1792 and by Richardson along the upper Saskatchewan in 1823. Its dissemination in America has been very rapid.

Canada Bluegrass Compared with Kentucky Bluegrass. These grasses may be distinguished from each other by several characteristics. Canada bluegrass has a compressed stem and more compact panicle than Kentucky bluegrass. It is less productive than Kentucky bluegrass, and it does not form so dense a sod. The herbage is a dark bluish-green color, and the stems bend at the nodes. Kentucky bluegrass has cylindrical, straight stems, and forms a dense sod, and the herbage is a true green in color.

In adaptation, Canada bluegrass has about the same climatic requirements as Kentucky bluegrass but is more resistant to summer heat and to drought. It is better adapted to poor and dry soils than Kentucky bluegrass but less adapted to moist or wet soils.

Like Kentucky bluegrass, Canada bluegrass may be used for both pasture and lawns. It has a somewhat higher nutritive value than Kentucky bluegrass. Where Kentucky bluegrass does well, it is preferable to Canada bluegrass when all things are considered.

BERMUDA GRASS (Cynodon dactylon)

Origin and History. Bermuda grass is a native of India and probably of other parts of the Old World in tropical and subtropical regions. It is not known when it was introduced into the United States, but in 1807 it was an important grass in the Southern states.

Description. Bermuda grass is a long-lived perennial spreading by runners or by rootstocks or by both, and by seeds. The runners usually vary in length from a few inches to 3 or 4 feet, but at times much greater length is obtained. The runners, which creep over the surface of the ground, often root at the nodes, at which places aerial stems are also produced. The stout rootstocks may be as large as a pencil and aid in making the plants very vigorous. By the growth of these organs a single plant may cover several square yards in area. The stems of the plants are very leafy, and, since several nodes are frequently very close together, the stems often appear to have several leaves from the same node. The leaves are flat, spreading, and may be distinguished from those of other grasses by the ligule, which is made up of a circle of white hairs.

Varieties. There is much variation in Bermuda grass. There are several varieties: the common Bermuda, St. Lucie grass, Brazil Giant Bermuda, and Florida Giant Bermuda. St. Lucie grass is identical in appearance with common Bermuda but lacks rootstocks and seldom lives through the winter north of Florida. It is rather dwarfish and is one of the best varieties for lawns and dooryards. Brazil Giant Bermuda is the most rank-growing kind and produces long runners, but it rarely produces seeds and has few or no underground rootstocks. The Florida Giant Bermuda grass is very similar to the Brazilian sort but has shorter runners, produces seed heads profusely, and has pale-green foliage in contrast with the rich blue-green herbage of the Brazil. Newer varieties are Coastal and Suwanee.

Adaptation. Bermuda grass fills about the same place in the South as Kentucky bluegrass does in the North. It is the most important perennial grass in the Southern states.

Bermuda grass requires warm weather during the growing season and will bear intense heat without injury. However, it is not resistant to cold and rarely persists where the temperature remains below zero for a great length of time, although the rootstocks will withstand for a short time somewhat colder air temperature. The leaves turn brown as a result of the first fall frost, and growth does not start in the spring until danger of frost is over. Bermuda grass will not stand shading well, and advantage is taken of this fact in eradication.

The grass will grow on all types of soil, but it thrives best on well-drained, rich, moist bottom lands. It apparently does not respond to applications of lime.

Uses. Bermuda grass is used for hay, pasture, lawns, and soil binding; it stands clipping well, and tramping does not injure it. The grass is difficult to eradicate, and for this reason it should not be sown in fields that are to be cultivated.

PERENNIAL RYE GRASS (Lolium perenne)

Origin and History. Perennial rye grass was the first grass to be cultivated to any large extent. It grows naturally in temperate Asia and southern Europe and in North Africa. The grass was early introduced into the United States.

Description. Perennial rye grass is a short-lived rapid-growing tufted perennial that ordinarily attains a height of 1½ to 2 feet. On poorer soils the grass lives only 2 years, and frequently, when seeded in hay mixtures, perennial rye grass will disappear after the first year as a result of shading by taller plants. Since the under surfaces of the leaves are bright and glossy, the grass has a noticeable appearance in the spring. Italian rye grass also has this appearance.

Perennial rye grass may be distinguished from Italian rye grass by the folded instead of convolute leaves and by the awnless lemmas.

Domestic rye grass is a trade name for seed that is usually a mixture of Italian and perennial.

Adaptation. Perennial rye grass is best adapted to regions with cool moist climates having mild winters. It grows to some extent during the winter and is not very resistant to cold. It is similar to orchard grass in cold resistance.

The plants are best suited to rich, moist, well-drained soils. Hot dry spells frequently kill or greatly retard the growth of the crop on uplands. The lack of drought resistance is a serious handicap.

Uses. Perennial rye grass makes rapid germination and growth, and for this reason it is frequently included in pasture and lawn mixtures. It serves excellently as a temporary covering, while the more valuable and permanent plants are being established. It is also used to sow on Bermuda pastures in the South for winter grazing.

ITALIAN RYE GRASS (Lolium multiflorum)

Origin and History. Italian rye grass is a native of southern Europe, northern Africa, and Asia Minor. It is an important grass in Europe but not of great importance in this country.

Description. Italian rye grass is not an annual, but under ordinary conditions it lives for only one year. Under favorable conditions the life is 2 years. It grows rapidly, forming tufts, and the plants reach a height of 1½ to 3 feet. The lemmas are awned and the leaves are inrolled at first.

Adaptation. Italian rye grass is best adapted to regions with moist mild climates, but it does best in the Atlantic and Pacific Coast states. It will grow on a great variety of soils but does best on rich loams with abundance of moisture. The crop does well under irrigation.

Uses. On account of the quick germination and growth, Italian rye grass is often used in pasture and lawn mixtures. In the South the seeds are sown on Bermuda grass sod to furnish winter grazing. Italian rye grass is sometimes used for an annual hay plant but the yields in this country are not nearly so good as those obtained in Europe.

BROME GRASS (Bromus inermis)

Origin and History. Brome grass, also called "smooth brome" and "awnless brome," is native to eastern Europe, Siberia, and China. It was introduced into the United States about 1884.

Description. Brome grass is a long-lived drought-resistant perennial with many underground rootstocks. Each plant may reach a diameter of a foot or more. Under favorable conditions the culms attain a height of 5 feet, and many usually arise from one plant. In a few years' time a dense sod is formed. The roots of 1-year-old plants have been found to reach a depth of 4 feet and those of 2-year-old plants a depth of 5½ feet.

Varieties. Lincoln is a variety of brome grass, probably of Hungarian origin, according to Hein,[3] that is well suited to the Midwest and the East. Strains similar to Lincoln are Achenbach, Fischer, and Elsberry. In the early years most of the seed in commercial channels came from the northern United States and Canada and was probably of Russian origin.

Adaptation. Brome grass is especially adapted to regions of low rainfall and moderate temperature during the growing season. It withstands cold exceedingly well, the most extensive culture being in the Dakotas, Montana, and western Canada. It is growing in favor, however, in the Midwest and the East, especially when grown in a mixture with alfalfa. High humidity and high temperatures during the growing season are both detrimental to the best growth of brome grass. The plants thrive best on loams and clay loams, but even on sandy soils they do well. The drought resistance of the grass is remarkable.

Uses. Brome grass is used for both pasture and hay. The seedlings start slowly, and the plants reach their best growth in the second and third years. It is peculiarly adapted for pasture purposes, being one of the most palatable of all grasses.

FESCUES (Festuca spp.)

There are a number of fescues, and they are important in limited areas of the country. It is scarcely feasible to do more than mention a few of them here. Meadow fescue (*Festuca elatior*) is a long-lived, tufted deep-rooted perennial, adapted to the timothy section of the country. It is used for both pasture and hay purposes. Tall fescue (*Festuca elatior*

var. *arundinaceae*), is a variety of meadow fescue. Alta fescue is a superior strain of tall fescue. Another strain of tall fescue, K-31, was developed by the Kentucky Agricultural Experiment Station. Sheep's fescue (*Festuca ovina*) is a long-lived perennial bunch grass. It is adapted to practically the same climatic conditions as Kentucky bluegrass and should be sown on land that will not produce better grasses, as it does reasonably well on such soils. Red fescue (*Festuca rubra*) is a long-lived perennial grass possessing underground stems; it does not grow in tufts. It is used mainly for lawns, especially on sandy or gravelly soils and on soils that are well shaded. It is also used on golf courses, but this use is diminishing.

TALL MEADOW OAT GRASS (Arrhenatherum elatius)

Origin and History. Tall meadow oat grass, also known as "tall oat grass," "meadow oat grass," and "evergreen grass," is native to southern Europe and northern Africa but extends into Persia. It was cultivated in Europe about the middle of the eighteenth century and in Massachusetts and South Carolina in the early part of the nineteenth century. Tall meadow oat grass is a standard grass in certain regions of Europe and is rather widely grown over the United States, but it is not of special importance in any section.

Description. Tall meadow oat grass is a hardy perennial growing to a height of from 30 to 60 inches and producing large tufts or bunches. The seeds, which somewhat resemble those of cultivated oats, are borne in panicles. The spikelets bear two florets, and the lower has a long, twisted, elbowed awn. Tall meadow oat grass may be used for either hay or pasture. It stands pasturing well and furnishes much grazing, as it comes early in the spring and remains green until late fall. The grass has a peculiar taste, but apparently this is not a serious drawback as the grass is readily eaten by livestock.

There is a variety of tall meadow oat grass known as *tuberosa*, which bears small bulbs at the base resembling a string of small onions and is sometimes called "onion couch." This variety yields less than the ordinary tall meadow oat grass.

Adaptation. Tall meadow oat grass in its adaptation resembles orchard grass in so far as climatic conditions are concerned. It will not endure so much cold as timothy, but it stands more summer heat. Tall meadow oat grass prefers well-drained soils and is especially adapted to light sandy or gravelly land; probably no other perennial grass does so well on poor land. However, it thrives on rich land and responds to the use of fertilizers. Tall meadow oat grass is very drought resistant, being

surpassed in this respect only by western wheat grass and *Bromus inermis*. It does not grow well in shade.

Uses. Tall meadow oat grass is most useful as a hay grass. It is usually seeded in mixtures with such plants as orchard grass and alsike clover. Rapidly growing plants, as Italian and perennial rye grasses, should not be included as the tall meadow oat grass seedlings will likely be injured by shading. The use of tall meadow oat grass is limited by the poor seeding habit of the plants and the low vitality of the seeds.

REED CANARY GRASS (Phalaris arundinacea)

Origin and History. Reed canary grass is native to the northern part of both hemispheres. Its cultivation began in England about 1824, in Germany about 1850, and along the North Atlantic coast in the United States shortly after its early use in Europe. It was cultivated in Coos County, Oregon, about 1885.

Description. Reed canary grass is a coarse perennial 2 to 8 feet tall, with leafy, short stems, tending to grow in dense bunches 2 or 3 feet in diameter and spreading underground by short, creeping rootstocks.

The seed mature from the top of the panicle downward and shatter very easily after ripening. The latter characteristic makes the seed difficult to save.

Adaptation. This grass does best when the climate is moist and cool. It is not sensitive, however, to heat or cold. It is not very successful when the average minimum temperatures in winter are above 45°F. or when average mean maximum temperatures in summer are above 80°F.

Reed canary grass thrives best on fertile, moist, or swampy soils. On the other hand, it makes a good growth on high, well-drained, rich soils if water is abundant. It is well adapted to irrigation in cool climates.

Uses. It is used mostly as pasturage, but its use for hay is increasing. It provides a long grazing season and gives large yields of hay.

SOUTHERN GRASSES

Much interest is now being manifested in the Southern states in regard to securing adapted grasses as the preliminary step in fostering the production of more and better livestock in that area. Among the grasses that have proved of value are Bermuda grass (*Cynodon dactylon*), carpet grass (*Axonopus compressus*), and paspalum or Dallis grass (*Paspalum dilatatum*). Other grasses of merit are Napier (*Pennisetum purpureum*), Para (*Panicum barbinode*), and Rhodes grass (*Chloris gayana*).

Certain Characteristics of Grasses. Some of the characteristics of the most common grasses are given in Table 19.

TABLE 19. CERTAIN CHARACTERISTICS OF GRASSES

Kind of grass	Time required for full development, years	Life of good stand, years	Tolerance of wet or dry soils	Tolerance of acid soils	Type of growth	Uses	Weight per bu., lb.	Rate of seeding alone, lb. per acre
Timothy	1	3–10	Not tolerant	Not tolerant	Semi-bunch	Hay	42–60	15
Redtop	1	Fairly permanent	Tolerant	Tolerant	Sod	Hay and pasture	36	10
Orchard	2	5–10	Tolerant	Tolerant	Bunch	Hay and pasture	14	25
Kentucky bluegrass	2–3	Permanent	Not tolerant	Not tolerant	Sod	Pasture and lawns	14	14
Canada bluegrass	2–3	Permanent	Tolerant of dry	Tolerant	Sod	Pasture	14–24	14–24
Bermuda	3–4	Permanent	Tolerant of dry	Tolerant	Sod	Pasture and hay	35–36	5
Perennial rye grass	1	1–2	Tolerant of wet	Tolerant	Semi-bunch	Pasture, lawns, and hay	24	30
Italian rye grass	1	1	Tolerant of wet	Tolerant	Semi-bunch	Pasture, lawns, and hay	24	30
Brome	2	Permanent	Tolerant of dry	Not tolerant	Sod	Pasture and hay	14	20
Tall meadow oat grass	2	5	Tolerant of dry	Tolerant	Bunch	Hay and pasture	10–16	40
Reed canary grass	2	Permanent	Tolerant of wet	Tolerant	Bunch	Pasture and hay	44–48	6

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Topics for Discussion

1. Do clovers and grasses that grow in pastures differ materially in their plant-food requirements from those which grow in rotations?

2. From the standpoint of total production of dry matter and digestible nutrients, which is the more efficient, grazing or making hay?

3. Are there any good reasons why hay meadows should not be permanently maintained?

4. What advantages do permanent pastures have over rotated pastures?

CHAPTER XXVIII

CLOVERS

The true clovers belong to the genus *Trifolium*. Therefore Japan clover, sweet clover, and the bur clovers are, strictly speaking, not true clovers.

General Description. The true clovers are annual, biennial, or perennial herbs with palmately trifoliate leaves. The inflorescence is a dense spike or head with flowers that vary in color with the species. The seeds, which are usually more or less kidney-shaped, are borne in small, mostly one-seeded pods that open circularly.

The members of this group have well-defined taproots; these go comparatively deep into the soil and have numerous lateral roots that spread in all directions through the surrounding soil mass. The clovers are rich in nitrogenous materials and are highly prized as feed for livestock. They are also valuable plants for soil-improvement purposes, since they, in common with other legumes, have the power of utilizing atmospheric nitrogen through association with the bacteria that are found on their roots. When clovers are turned under, they decay rapidly and soon become incorporated with the soil. The clovers are so highly valued by farmers that in many sections their presence on farms is considered indicative of prosperous conditions.

RED CLOVER (Trifolium pratense)

Origin and History. Red clover was not cultivated in ancient times except apparently in Media and adjacent regions. It is a native of Europe, Algiers, Asia Minor, Turkestan, southern Siberia, and the Himalayas. It is known to have been cultivated in Spain and Italy as early as the fifteenth and sixteenth centuries, and it reached England in 1633 through Flanders. The first published mention of it in the United States was in 1747 by Jared Eliot. The spread has been rapid in the United States.

Description. The red clover plant is usually biennial, although some plants in a field seem to be short-lived perennials. The plants, if allowed to produce seeds, usually die, even though they may not be 2 years old. Often in good seasons the plants have a tendency to bloom late in the fall. It is a common practice to graze or mow off the crop to prevent production of seeds at this time.

The plant is herbaceous and consists of many leafy stems arising from

a crown. The flowers, which are generally rose-pink and frequently numerous, are borne in compact clusters or heads at the tips of the branches. Each leaf consists of three oblong leaflets and usually has a pale spot in the center. The roots are usually deep, much branched, and generally well supplied with nodules. Hays,[1] at the Minnesota Experiment Station, found that a red clover plant at the age of 5 months had a taproot that descended to a depth of 5½ feet. The secondary roots were still deeper. However, there was greatest root development in the surface 1½ feet of soil.

Adaptation. The red clover plant is grown most extensively in the north central and northeastern portions of the United States.

Red clover is best suited to regions with abundant rainfall and without extreme summer and winter temperatures, although it is grown in Maine, Minnesota, and parts of Canada. It is quite resistant to cold, and certain strains seem more resistant than others. However, some strains, such as the Italian, are especially susceptible to cold injury. The crop is not suited to shady places.

Red clover will grow in almost any kind of soil on which corn will grow. It does best on the heavier kinds of soils which are deep, well-drained, productive, and rich in lime, and which have a rather high content of organic matter. The moisture conditions of the soil are important. The crop will not thrive on open soils that tend to dry out rapidly, nor will it do well on poorly drained soils.

Clover Failure. For a number of years it has been becoming increasingly difficult to secure good crops of red clover. The cause has been attributed to many factors. The influence of the source of seed became generally recognized a few years ago (Pieters,[2] Pieters and Hollowell[3]). Tests show that better yields of red clover are generally secured when locally grown seed is used than when seed from foreign countries or from other sections of the United States is used. Italian-grown red clover seed give uniformly worse results in the United States than domestic-grown seed. French-grown and other foreign-grown red clover seed give lower yields than domestic seed. In the southern clover belt of the United States, locally grown seed, or seed grown in states near by, such as Tennessee, Virginia, Indiana, Kentucky, Maryland, and parts of Ohio, usually give better results than seed grown in the northern or northwestern portions of this country. Similarly, southern-grown red clover seed do not give as good crops when planted in northern latitudes as northern-grown seed.

The inferiority of the foreign-grown clover seed when grown in this country, as compared with domestic seed, is due largely to the attacks of the anthracnose or scorch disease (Monteith[4]) and that of the potato

leaf hopper (Monteith and Hollowell[5]). The superiority of locally grown seed for given areas is due in large measure to the natural development of strains resistant to the anthracnose prevalent in the area. Red clover is attacked by one kind of anthracnose in the southern clover belt and another kind in the northern belt.

The potato leaf hopper does its most serious damage in hot dry summers, and anthracnose, in hot, moist summers. In order to reduce the injury from the attacks of anthracnose and the hopper, late-summer instead of spring seedings and the use of resistant strains of red clover are suggested.

Varieties of Red Clover. There are a number of varieties of red clover, and each has more or less of a special adaptation. The two main varieties in the United States are medium red clover (*Trifolium pratense*) and mammoth or sapling clover (*Trifolium pratense perenne*). The latter blooms about 2 weeks later than the former, the stems are usually solid as compared with the hollow stems of *Trifolium pratense*, and it will produce either a crop of hay or a crop of seed in the same season, while medium red clover may produce both. Since mammoth clover blossoms with timothy, it is usually better for growing for hay with timothy than is medium red clover.

Among the important strains of red clover are Midland and Cumberland, according to Hollowell.[6] Midland red clover originated as a composite of equal proportions of four old strains, one each from Ohio, Indiana, Illinois, and Iowa. It is winter hardy and shows some resistance to northern anthracnose. It yields better than common red clover. It is particularly well adapted to the middle or central part of the Corn Belt states.

Cumberland originated as a composite of equal proportions of three strains, one each from Kentucky, Tennessee, and Virginia. It is moderately resistant to southern anthracnose, somewhat resistant to crown rot, and yields much better than unadapted red clover in the southern red clover belt, for which section it is especially well suited.

Uses. Red clover is the main leguminous forage crop in the region to which it is adapted. It is used primarily for hay purposes and is sown extensively with timothy. Red clover is also a good pasture plant and is used to some extent for silage and soiling purposes. It fits well into many crop rotations, and the effect of the crop on the yields of subsequent crops in the rotation is generally very beneficial.

ALSIKE CLOVER (Trifolium hybridum)

Origin and History. Alsike clover is so named from the locality in Sweden from which the plant came to England. It is a native of tem-

perate Europe and Asia and occurs in Algiers. Alsike clover has been cultivated in its native home since the tenth century. However, it was not introduced into England until 1834 and was not brought into the United States until 1854. It was thought at one time to be a hybrid between red and white clover but is now recognized as a separate species.

Description. Alsike clover is a perennial plant, and the smooth leafy stems arise from a crown. The stems are erect or ascending when

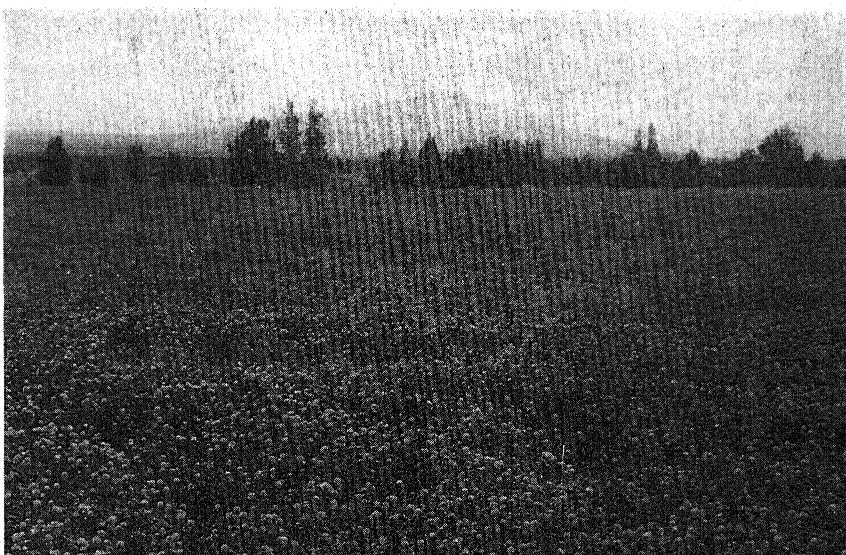

FIG. 55. Alsike clover in Deschutes County, Oregon. (*U.S. Dept. Agr. photograph by Ackerman.*)

crowded, but when the plants are isolated the habit of growth is spreading. Each leaf is composed of three leaflets, and the heads of the flowers are partly pink and partly white in color. Sometimes the flowers of some heads are all white and again all pink. Alsike clover is more leafy than red clover and differs in habit of growth. In red clover the main axis terminates in a flower, and growth is limited; in alsike clover the main axis continues to grow. In either clover, new branches may arise from leaf axils, but only in the case of alsike clover does the main axis of the plant continue to grow. Under favorable conditions the stems reach a length of 2½ to 5 feet, but ordinarily about 2 feet.

Hays[1] at the Minnesota Experiment Station reports the taproot of a 1-month-old plant to be 9½ inches long; at 2 months he reports a length of more than 2 feet. The taproot does not remain prominent, as the secondary roots become comparatively large. At the same age the root development of alsike clover is greater than that of red clover.

Adaptation. In the United States alsike clover is generally grown north of the Ohio and the Potomac rivers, and as far west as the Dakota-Minnesota boundary. The crop is also grown in Idaho and on the coast of Washington and Oregon but is not extensively grown in the South, being limited largely to Virginia, Kentucky, Tennessee, and Missouri.

Alsike clover requires a cool climate with abundant moisture, as it is very cold resistant, being more so than red clover. Although drought greatly reduces the yield of alsike clover, it is probably as resistant to dry weather as red clover. The plants do well on nearly all kinds of soils, provided there is abundant moisture present, but the most luxuriant growth is made on the heavier soils. Alsike clover will grow well on wet lands and on lands that will not produce red clover on account of "clover failure." The crop responds to lime applications, but it is not so sensitive to soil acidity as red clover.

Uses. The production of alsike clover is on the increase. It is used largely where red clover yields are decreasing. It may be said that where red clover does well, alsike is not generally used, because the former gives larger yields. Alsike clover makes an excellent hay. However, it is generally not seeded alone for hay but is usually seeded with timothy or with timothy and red clover. The plants are especially suited for pasture mixtures.

WHITE CLOVER (Trifolium repens)

Origin and History. White clover, also known as "Dutch clover," is native to temperate Europe and Asia, and occurs in the Azores. The plant was apparently first cultivated in Holland. The presence of white clover in the United States was mentioned by Jared Eliot in his writings of 1747 and by Strickland in 1794 in an account of his travels in the United States. In this country white clover spreads rapidly in certain sections, usually in association with Kentucky bluegrass.

Description. White clover is a long-lived, shallow-rooted perennial. It differs greatly from red and alsike clovers in two ways: it has a prostrate, creeping habit, and the stems root at nearly every node. The plants spread rapidly, frequently form a dense turf, and are seldom injured by mowing and grazing.

Hays[1] at the Minnesota Experiment Station found a 1-month-old plant having a taproot 4½ inches long and many branch roots. At 2 months the taproot was 2 feet long, and roots were forming at the nodes of the creeping branches. The taproot apparently dies in 1 or 2 years.

Adaptation. White clover is widely grown, occurring in all parts of the country. It thrives best under cool, moist climates, and in the South the greatest growth is made in cooler seasons of the growing period.

White clover will grow on almost any kind of soil, provided sufficient moisture is present, but the best growth is made on the heavier, well-drained soils that are rich in humus. It does well in shady places.

Uses. White clover is a pasture plant, and in the seeding of pasture mixtures a small amount of seed of this plant is usually included. However, in some sections of the country white clover and bluegrass appear naturally as soon as the land is cleared.

LADINO WHITE CLOVER (Trifolium repens latum)

Origin and History. Ladino clover apparently came from and derived its name from Lodi, a town in the Province of Lombardy, northern Italy, where it was originally found growing extensively. Seed was first brought to the United States in 1900, but it was not until 1912 that the seed was imported in quantity and the crop successfully grown in the irrigated valleys of the Western states.

Description. Ladino clover is a giant, rapid-growing, perennial type of common white clover, spreading by creeping fleshy stems that root at the nodes. The leaves, stems, and flower heads grow from two to three times as large as those of common white clover. However, the shape, color, and markings of the leaves, and the shape and color of the flower heads are similar. The size and color of Ladino clover seed is the same as that of common white clover.

Adaptation. Ladino clover is especially adapted to the Northeastern states, but it is also successfully grown in the Lake and Corn Belt states and in the upper section of the Southeastern states. Its culture and soil requirements are somewhat more exacting than those of common white clover, but the great number of uses and its high livestock-carrying capacity and high nutritive value of feed encourage its use. It grows well in mixtures of timothy and orchard grass. Good stands last from 4 to 7 years.

Uses. Ladino clover has many uses, such as pasture, hay, and silage. It is, however, primarily a grazing crop.

CRIMSON CLOVER (Trifolium incarnatum)

Origin and History. Crimson clover, also known as "scarlet," "incarnate," and "German" clover, is a native of Europe and is cultivated in Italy, France, Spain, Germany, Austria, and Great Britain as a forage and green-manuring crop. The wild plant has yellow flowers; one form has rose-colored flowers and is shorter, less vigorous, and more hairy than the cultivated form. It was introduced into the United States in 1818 and widely distributed by the United States Patent Office in 1855.

Description. Crimson clover is a winter annual; *i.e.*, it usually makes its early growth in the fall, passes the winter in a dormant but green state, makes a rapid early spring growth, matures, and dies before summer. The stems branch from the base and are nearly erect when the plants are crowded but may be somewhat spreading in the case of isolated plants. Each stem is terminated by a spike or head, which is usually a brilliant crimson when in bloom. The vegetative portions of the plant are hairy.

Adaptation. Crimson clover is best suited to the sandy soils of the Atlantic Coastal Plain. The crop does not thrive under conditions of extreme cold or heat but grows best in those sections having a long period of relatively mild, moist weather. It does not survive the winter ordinarily north of the latitude of southern Pennsylvania, and in the South the dry hot weather in the fall and spring is very detrimental. It grows well in the shade.

Dixie is a new hard-seeded variety of crimson clover that gives promising results. It is more widely adapted than common crimson clover, as it grows well in the Gulf Coast section and appears to be more winter hardy. The seed and plants of Dixie and common crimson clover cannot be distinguished from each other.

Crimson clover will grow well on almost all soils, provided they are well drained, productive, supplied with organic matter, and inoculated with the proper bacteria. The crop responds to applications of lime but is less sensitive to soil acidity than some of the other clovers. Crimson clover can be grown successfully on poor soils by proper treatment as regards liming, inoculating, fertilizing, etc.

Uses. Crimson clover may be used for a number of purposes, such as hay, soiling, and pasture. However, the crop is chiefly grown as a cover crop and as a green-manure crop.

SWEET CLOVER (Melilotus spp.)

Origin and History. Sweet clover is a native of western Asia and has been known for about 2,000 years in the region of the Mediterranean. The white sweet clover was introduced into the United States in 1738, but only in the last 35 to 40 years has the crop been grown extensively.

Description. There are both biennial and annual forms. The stems vary in height from 3 to 6 feet and bear numerous sweet-scented flowers in narrow, erect racemes. The seeds are borne singly in reticulate pods. All portions of the plant contain a bitter-tasting compound known as "cumarin," which has a sweet vanillalike odor.

Adaptation. Sweet clover has a wide range of climatic adaptation and can be grown in nearly all parts of the country. It does equally

well under humid and under dry conditions, and, as long as moisture is abundant, neither the hot climate of the South nor the cold weather of the North apparently injures the crop.

Sweet clover also has a wide range of adaptation as far as the soil is concerned. It can be grown on all kinds of soils, but it is especially important to have sufficient lime present. The plants have well-developed root systems and can apparently withstand drought nearly as well as alfalfa. On wet or poorly drained soils the crop thrives better than red clover or alfalfa.

Uses. The crop has many uses. It may be used for pasture, hay, silage, soiling, or for soil improvement; it may also be used as a honey plant.

Related Species. There are four kinds of sweet clover grown in the United States: biennial white sweet clover (*Melilotus alba*), biennial yellow sweet clover (*Melilotus officinalis*), annual yellow sweet clover (*Melilotus indica*), and annual white sweet clover or Hubam (*Melilotus alba* var. *annua*).

Varieties. Four new and superior varieties of biennial white and one of biennial yellow sweet clover are reported by Hollowell.[6] Of the biennial white varieties, Evergreen and Sangamon are recommended for use in the Corn Belt and eastern edge of the Great Plains, Spanish for the Corn Belt, Great Plains, and sections of the Intermountain Region, and Willamette for the Pacific Northwest. The biennial yellow variety is Madrid. It is recommended for use in the Great Plains and Corn Belt.

PERSIAN CLOVER (Trifolium resupinatum)

Origin and History. Persian clover is a native of southern Asia Minor and the Mediterranean countries. It is a valuable pasture and hay crop in Persia and Egypt. It has proved also to be a useful plant in the southern part of the United States. In 1928 it began to spread in a section near Hamburg, Louisiana, following the Mississippi flood of the previous year. Since then it has spread rapidly through sale of seed and natural reseeding. Earlier attempts to introduce the clover into the United States on a commercial scale were unsuccessful, according to Hollowell.[7]

Description. Persian clover is a winter annual. The seeds germinate in the fall, and the plants grow during the winter in the form of a low rosette. During the following spring many slender, upright flower stems develop. Seed is produced in late spring and early summer, and the plant then dies. The plant grows from 8 to 24 inches tall. If grazed heavily, or if the stand is sparse, it has the appearance of a low, spreading plant. In the rosette stage the leaves are similar to those of young white

clover plants, but the leaflets are somewhat more tapering at the base than those of white clover. Persian clover stems do not creep on the surface of the soil nor root at the nodes as do white clover stems. The flowers are light purple in color and form a head that is somewhat flat.

Adaptation. Persian clover is best adapted to the low-lying heavy moist soils of the Southern states. It is not recommended for upland sandy soils or for the Northern states.

Inoculation is necessary when the seed is to be sown on land that has not grown the crop before. Persian clover grows successfully on medium to slightly acid soils, but liming is recommended for best results. It also responds well to the use of fertilizer containing phosphoric acid and potash.

After Persian clover is once established, it does not require reseeding, as an abundance of seed is produced for volunteer stands.

Uses. Persian clover is primarily a pasture and hay crop. It supplies good grazing from late winter to late spring.

LESPEDEZA (Lespedeza spp.)

Origin and History. Lespedeza (Lespedeza striata) was formerly known as "Japan clover." The plant is a native of eastern Asia, being found in Japan, Korea, Manchuria, Mongolia, and China. Lespedeza was introduced in the United States before 1846. The first authentic record of the plant in this country dates back to August, 1846, when Thomas C. Porter, Monticello, Georgia, discovered a specimen that is still preserved.

Description. Lespedeza is a summer annual that grows to a height of 4 to 6 inches under ordinary conditions; under favorable conditions, however, as on alluvial bottom land, it reaches a height of 15 to 24 inches.

In thin stands the plants are much branched and spreading or prostrate, but in thick stands the branching is less and the stems are more or less erect. The growth starts rather late in the spring, the small purple blossoms appear in the late summer, and the seeds are matured in the fall. Under favorable circumstances the crop readily reseeds itself, and for this reason a stand is maintained from year to year by natural seeding.

The roots are not deep. Dodson[8] and others, however, at the Louisiana Experiment Station, estimated that the stubble and the roots to a depth of 12 inches constitute about one-third of the weight of the hay removed. Essary,[9] in Tennessee, found that the roots penetrated to a depth of 24 inches even in hard clay soils.

Adaptation. Lespedeza occurs in more or less abundance from central New Jersey westward to central Kansas and southward to the Gulf of Mexico. Over the northern part of this area the plants grow only tall

enough for pasturage, but in the South the crop becomes sufficiently high for mowing as hay. The crop was widely distributed by the movement of cavalry during the Civil War.

Lespedeza thrives in hot weather and seldom begins growth in the spring until warm weather. Since it is sensitive to frost, it does not make early spring or late fall growth.

The crop will grow on all kinds of soils as long as they are well drained near the surface. However, on the richer lands the yield is higher. Fertilization and liming is very profitable in growing lespedeza. It should be stated further that lespedeza is well suited for pasture on poor or "worn-out" lands.

Varieties. The two older varieties of the common lespedeza (*Lespedeza striata*) are Kobe and Tennessee 76. The former came from Kobe, Japan, and the latter was developed at the Tennessee Agricultural Experiment Station (Essary[9]).

Kobe lespedeza is larger in size than common lespedeza, yields more, and matures later. In other respects it is very similar to the common.

Tennessee 76 lespedeza, unlike common lespedeza, has an upright habit of growth and is, for this reason, especially suited for hay production. It grows larger than common lespedeza and matures later, being very similar to Kobe in these respects.

Korean lespedeza (*Lespedeza stipulacea*) differs mainly from common lespedeza in having larger and coarser growth and larger leaves and in being about 2 weeks earlier in maturity. It may be grown about two hundred miles farther north than common lespedeza and at higher altitudes.

McKee[10] reports two new varieties of Korean lespedeza: Early Korean and Climax. Early Korean outyields regular Korean and may be grown farther north, as it matures about 2 weeks earlier. Climax also outyields regular Korean but is later maturing and therefore affords later pasturing.

Harbin is one of the newer varieties of lespedeza. It has a dwarf habit of growth and should not be planted south of Michigan (Pieters[11]).

Related Species. The lespedezas, common and Korean, are the only annuals among the 125 species, according to Pieters.[12] The other lespedezas are perennials. One of the best known of the perennials is *Lespedeza sericea.* It is not of so great economic importance as the common and Korean lespedezas. However, it is grown for hay, grazing, and soil-erosion control. Because of its high tannin content when taller than 10 or 12 inches, it is recommended that it be cut for hay in the early stages of growth.

Uses. Lespedeza is used extensively for pasture, and in certain sections of the South it is important as a hay crop, frequently yielding 1 to 3

tons of field-cured hay per acre. It is well adapted to sowing in mixtures with such grasses as Bermuda, redtop, and Johnson.

BUR CLOVERS (Medicago spp.)

Kinds of Bur Clover. There are about thirty-five species of bur clover, but the only types of importance cultivated in this country are the two following: spotted or southern bur clover (*Medicago arabica*) and toothed or California bur clover (*Medicago hispida denticulata*). Both of these species are natives of the Mediterranean region and were early introduced into the United States.

The spotted bur clover can be distinguished from the California species by the purple spot on the center of each leaflet. Also, the pods of the former contain two to eight seeds, whereas those of the latter usually contain three and sometimes five seeds.

Description. The two species under consideration are annuals, having small yellow flowers in clusters of five to ten, and the seeds are borne in coiled pods that are usually beset with spines; hence comes the name "bur." The plants ordinarily branch profusely from the crown and usually have from ten to twenty or more spreading or decumbent branches. The branches are from 6 to 30 inches long, and well-developed plants frequently contain as many as 1,000 pods. The roots are fibrous and are comparatively shallow. Under favorable conditions these clovers reseed themselves naturally each year.

Adaptations. Agriculturally, the bur clovers are of importance only where the winters are mild. The spotted or southern bur clover is limited particularly to the Cotton Belt, and the toothed or California bur clover is found especially on the Pacific Coast west of the Cascade and Sierra Nevada ranges. However, both species are found in each region.

The bur clovers are winter annuals and are best adapted to regions with mild, moist winters. Toothed bur clover seems to be less cold resistant than southern bur clover.

These clovers are best suited to loam, but they will grow on all kinds of soils. Usually moist well-drained soils are preferred, but frequently the California bur clover does well on poorly drained soils. Lime is not necessary for the growth of these plants, but they respond to its use.

Uses. The bur clovers serve a very good purpose as a cover and green-manure crop. The crop is used to a great extent for pasture, especially for hogs, cattle, and sheep, and is very satisfactory for seeding with Bermuda grass. Under favorable conditions, bur clover becomes tall enough to be used as hay. Cauthen, [13] at the Alabama Experiment Station, reports a yield of 3,493 pounds of bur clover hay per acre.

CROTALARIA (Crotalaria striata)

Origin and History. Crotalaria is a legume native to Africa, India, South America, Mexico, and the United States. As a result of its introduction into Florida in 1909 by the late Dr. C. V. Piper, of the U. S. Department of Agriculture, and tests at the Florida Agricultural Experiment Station, its use as a soil-building crop is increasing in the United States.

Description. It is an erect-growing annual, 6 or more feet tall. The stem is woody, and the yellow flowers are borne in long terminal racemes. The roots grow to great depths. The plants are indeterminate in growth, as flowers and both immature and mature pods may be found on one plant at the same time.

The plants bloom in from 60 to 70 days after they appear above the ground, and the seed begin to mature in about 90 to 100 days after the plants appear. Inoculation is usually not necessary, as the same organism that inoculates cowpeas inoculates Crotalaria. Cowpeas have been grown for years in the sections best suited to Crotalaria, and the soils are therefore well inoculated.

Adaptation. Crotalaria is well adapted to all parts of the Cotton Belt. In fact, it has been grown as far north as Ohio and Illinois, but seed did not mature.

It will grow well on practically all soils except those which are poorly drained. It is an excellent crop for the unproductive sandy soils of the Southeastern and Southern states. In these states the crop reseeds itself, and when allowed it will grow on the same land year after year.

Uses. Tests conducted by Prof. W. E. Stokes, of the Florida Agricultural Experiment Station, show that Crotalaria is the best crop in the state for building up unproductive soils. Its chief value is for soil-improvement purposes. It is not readily eaten when either green or dry by livestock.

Related Species. There are a number of species of Crotalaria, the next in importance to *C. striata* is *C. spectabilis*, which also is an annual. Certain ornamental species of Crotalaria are used in the Old World as garden plants, as well as for soil-improving purposes.

Culture. *Crotalaria striata* may be seeded from early spring to early summer. It should not be seeded so early as to be killed by frost or so late that the plants will not have sufficient time to mature seed, if it is desired that the crop reseed itself. The plants are killed by cold when the temperature reaches 28°F.

The usual rate of seeding is from 10 to 20 pounds per acre when sown broadcast and from 3 to 5 pounds per acre when seeded in rows 4 or 5 feet

apart. The row method of seeding is preferred when the crop is grown for seed production.

The seed may be broadcast on unprepared ground and covered by disking. The chances are, however, that it will pay to prepare a good seedbed before seeding the crop.

The yield of seed varies, but in Florida from 275 to 600 pounds per acre have been secured. The yields of green material usually range from 5 to 15 tons per acre.

Certain Characteristics of Clovers. Some of the characteristics of the most common clovers are given in Table 20.

TABLE 20. CERTAIN CHARACTERISTICS OF CLOVERS

Kind of clover	Time required for full development, yr.	Life of good stand, yr.	Tolerance of wet or dry soils	Tolerance of acid soils	Type of growth	Uses	Weight of seed per bu., lb.	Rate of seeding alone, lb. per acre
Red.......	1	Biennial	Not tolerant	Not tolerant	Erect	Hay and pasture	60	12
Alsike.....	1	2–5	Tolerant of wet	Tolerant	Spreading	Hay and pasture	60	10
White.....	2–5	Fairly permanent	Fairly tolerant	Tolerant	Prostrate	Pasture	60	8
Ladino....	1	Perennial	Fairly tolerant	Fairly tolerant	Spreading	Pasture and hay	60	2
Crimson...	1	Winter annual	Not tolerant	Fairly tolerant	Erect	Green manure and pasture	60	15
Persian....	1	Winter annual	Tolerant of wet	Fairly tolerant	Spreading	Pasture and hay	60	8
Sweet..... (biennial)	1	Biennial	Not tolerant	Not tolerant	Erect	Pasture, green manure, and hay	Hulled 60 Unhulled 32	15 30
Lespedeza	1	Summer annual	Not tolerant of wet	Tolerant	Spreading	Pasture	25	20
Lespedeza sericea	1	Perennial	Tolerant	Tolerant	Erect	Hay, pasture, erosion control	Hulled 60 Unhulled 34	20 45
Bur.......	1	Winter annual	Not tolerant of wet	Tolerant	Prostrate	Green manure and pasture	Hulled 60 Unhulled 10	15 30
Crotalaria	1	Summer annual	Not tolerant	Tolerant	Erect	Soil improvement	60	15

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Topics for Discussion

1. Do clovers always leave the soil more productive where they have been grown?

2. What are the three clovers that are most likely to catch and thrive under the conditions in your section?

3. What are the relative lime requirements of the five most important clovers in your section?

4. Which is the most efficient clover from the standpoint of soil improvement alone for your locality?

CHAPTER XXIX

ALFALFA (Medicago sativa)

Alfalfa is the most important forage crop in the United States at the present time, being followed closely in tonnage only by timothy and clover. It thrives best in the irrigated sections of the West and does well under favorable conditions on the rich soils of the East. The crop does best on

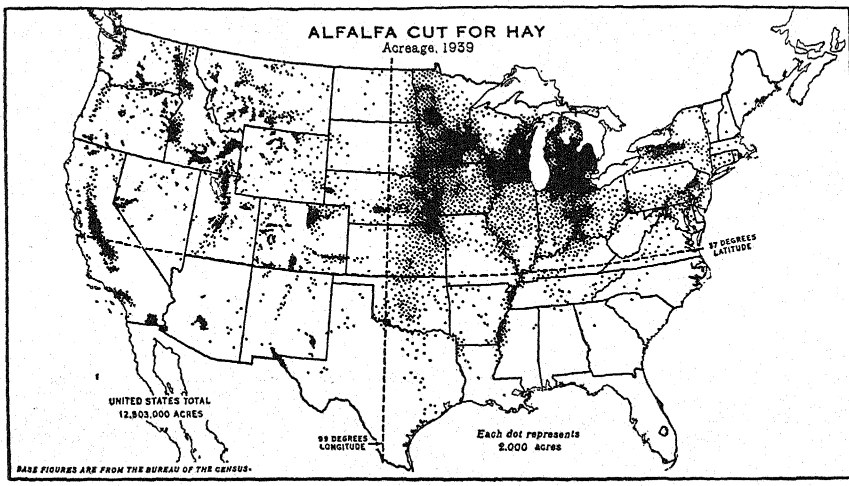

FIG. 56. The acreage of alfalfa cut for hay in 1939 constituted about twenty per cent of the total acreage of hay. Alfalfa is the leading hay legume in the United States and is used exclusively for a cover and green-manure crop in very limited areas. In rotations, alfalfa is recognized as one of the more important soil-improving crops. Many types of alfalfa are grown and are adapted to various soils and climatic conditions. Resistance to disease and insect injury is high. Alfalfa thrives best on well-drained soils that are rich in lime and have an alkaline reaction. It produces two to six cuttings a year, yielding a large tonnage in the irrigated lands of the West. The three leading states in the acreage of alfalfa cut for hay are Michigan, with 1,213,000 acres; Minnesota, 1,184,000 acres; and Wisconsin, 1,137,000 acres. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

soils that are abundantly supplied with lime, and the hay can be most easily cured in a climate where rain is not abundant during the summer season. The climatic and soil requirements of alfalfa, especially the former, are very important in the production of the crop.

Production in the United States. Figure 56 shows the acreage of alfalfa in the United States in 1939.

The average production of alfalfa hay, during the 10-year period

1934–1943, in the leading six states was as follows: California, 3,304,000 tons; Minnesota, 2,234,000 tons; Wisconsin, 2,191,000 tons; Iowa, 1,940,000 tons; Idaho, 1,874,000 tons; and Michigan, 1,831,000 tons. These six states produced 47 per cent of the total crop during that period.

Historical. Alfalfa was known to the Greeks and Romans. It was introduced into Greece from Media about 470 B.C. The crop is probably a native of Media or Persia, as the wild alfalfa plants of that region closely resemble the cultivated strains. The crop was carried to Spain from Italy and introduced into Mexico from Spain and thence to Chile. From the latter country the crop was brought to California about the middle of the nineteenth century.

It is interesting to find that, although alfalfa was introduced into the eastern part of the United States in the early part of the nineteenth century, about 1820 in New York, the rapid development of the crop was in the West. The crop is more adapted to the conditions existing in the West than to those in the East, and the rapid spread of the crop in the United States dates from the later introduction in California.

Classification. The commonly cultivated alfalfas of this country may be classified into five more or less distinct groups. Each group contains strains or varieties that differ to some degree. The groups are (1) common; (2) Turkestan; (3) variegated; (4) nonhardy; and (5) yellow-flowered.

The *common* group includes the ordinary purple-flowered, smooth alfalfa, of which there are many regional strains grown throughout the western part of the United States. The term "common alfalfa" includes all the alfalfas that are not clearly of hybrid origin or that do not have fairly distinct and uniform varietal characteristics.

The common group contains two general types of plants. One, as compared with the other, grows off more quickly after being cut, produces heavier yields, is more erect, has smaller crowns, which are produced above the surface of the ground, and is less resistant to winter conditions. The other type is slightly procumbent, has broad crowns that are produced somewhat below the surface of the ground, and is hardy. These facts are the basis for the production of regional strains. Some of the regional strains of common alfalfa are "Kansas grown," "Montana grown," and "Dakota grown."

Some of the imported strains of common alfalfa are Argentine, African, and Provence (Westover)[1]. In keeping with Federal government regulations, 10 per cent of the Argentine seed must be stained orange-red, and 10 per cent of the African and Provence seed stained red, before it is permitted entry.

The *Turkestan* group includes the alfalfa produced from seed coming

from that country, regardless of its characteristics or history. The plants have purple flowers, and it is practically impossible, when only a few plants are considered, to distinguish Turkestan from common alfalfa. However, the Turkestan plants are somewhat shorter and more spreading in habit of growth and slightly more hairy than common alfalfa. It was first supposed that this alfalfa would be suited to the cold dry regions of this country. However, tests have shown that commercial Turkestan alfalfa yields less than the American-grown strains, is shorter lived, and is less hardy than such varieties as Grimm and Baltic. Turkestan alfalfa can, in most cases, be identified by the seed of Russian knapweed (*Centaurea picris*), which it nearly always contains. The leading varieties are Turkestan, Hardistan, and Orestan.

The *variegated* group is thought to have originated from hybrids between the ordinary purple-flowered alfalfa and the yellow-flowered species. Subsequently, intercrossing occurs, and there is a considerable range of flower colors with purple predominating. However, brown, green, greenish-yellow, and smoky hues occur, but occasionally pure yellow flowers appear. In addition to the flower colors, variegated alfalfa can be often identified by the form of the seed pods. Some of the pods are circular, semicircular, or loosely coiled, but the predominating number resemble closely the compactly coiled pods of the common alfalfa. As a rule, the variegated alfalfas are more resistant to cold and drought than the other commercially grown alfalfas. The main varieties of this group are Grimm, Cossack, Ladak, Baltic, Canadian variegated, Hardigan, and Sand Lucern.

The *nonhardy* group is distinct from the regional strains of common alfalfa but has been developed in the southern part of the United States. The varieties of this group recover quickly after cutting and have a long period of growth but are seriously affected by low temperature. The two strains of this group grown commercially in this country are Peruvian and Arabian.

The *yellow-flowered* group includes various forms of yellow-flowered species. They are frequently called "Siberian" or "sickle" alfalfa. However, not all yellow-flowered alfalfas came from Siberia. The yellow-flowered alfalfas can be readily distinguished from those of other groups by the yellow flowers and crescent or sickle-shaped pods. The plants are usually procumbent, and the taproot is usually lacking. The root system, however, is much branched, and the crowns are produced somewhat below the surface of the ground. This group is cold and drought resistant.

These alfalfas are of but little commercial value in the United States but on account of their hardy characteristics they may prove of worth

for hybridizing purposes. Two varieties of this group are Semipalatinsk and Orenberg.

Distribution of Varieties and Strains. The different kinds of alfalfa frequently have different adaptations, and for this reason a variety that does well in one region may not be adapted to another region. The Peruvian alfalfa is adapted to the extreme southern and western parts of the United States, but it does not thrive in the other sections as well as some other sorts. In the selection of strains or varieties of alfalfa, the results of tests carried on in the region in question should be studied and adapted to the kinds chosen.

New Varieties and Their Development. A number of varieties of alfalfa have been described by Westover.[1] The results of variety tests show that there are wide differences in adaptation of varieties and strains of alfalfa.

New varieties, reported by Westover[1] and Tysdal,[2] that show superiority are Ranger, Buffalo, Atlantic, and Nemastan. These varieties were developed through selection.

Tysdal[2] states, "Plant breeders can use ordinary selection methods and produce good strains of improved alfalfa, but the best strains with maximum improvement can be produced only by making use of hybrid vigor." He reports that in a 10-year test at the Nebraska station the alfalfa "hybrids showed a superiority of from 20 to 27 per cent over Grimm. In a seed-production test at the Utah station some of the hybrids yielded 660 pounds of seed to the acre, while Grimm produced 450 pounds an acre."

Tysdal[2] found many of the hybrids to be resistant to bacterial wilt and to attacks of the potato leaf hopper. Alfalfa subjected to leaf-hopper attacks (alfalfa yellows) is greatly reduced in carotene content (Vitamin A). "Tests under leaf-hopper infestation have shown that more resistant hybrids have twice as much carotene as standard varieties."

Although the production of alfalfa hybrids is still in the experimental stage, hybrid alfalfa appears to have a very definite place in alfalfa production and improvement (Tysdal and others[3]).

Botanical. Alfalfa belongs to the family *Leguminosae* and genus *Medicago*. There are several species and frequently a number of varieties within a species.

The alfalfa plant is a perennial, and the stems, which bear short, leafy branches, arise from the crown and usually vary in number from five to twenty. However, in rare instances a hundred or more stems may be produced. The plants vary in height from 18 inches to 3 feet. The seeds are borne in spirally twisted pods, which have one to three coils, each coil containing one to eight seeds.

The crown may be at the surface of the ground or slightly beneath and is made up of a series of short branches. Buds arise from any point on these branches, and generally, as the first shoots reach maturity, new buds develop. In the humid regions the height of these new shoots is a good indication of the proper time for cutting the crop.

Roots. The roots of alfalfa are very long and penetrate to a great depth as compared with most other field crops. Hays,[4] at the Minnesota Experiment Station, found the roots of 2-month-old plants to be about 3 feet long. The taproot was present with small branches. At the age of 5 months the taproot had penetrated to a depth of 6½ feet, and some of the side roots were nearly as deep. It was noted that at a depth of 5 feet some of the larger roots possessed branch roots. Headden,[5] in Colorado, observed roots 9 feet long on plants 9 months old. On plants 9 years old, growing on mellow, dry soil, but not irrigated, roots were found at a depth of 12½ feet. From two samples of plants, roots were secured measuring 11½ and 11¾ feet in length, respectively. Ten Eyck,[6] in Kansas, traced the roots of 3-year-old alfalfa plants to a depth of 8½ feet. These data indicate that alfalfa plants very early develop extensive root systems and that the roots reach a comparatively great depth. The roots of the different kinds of alfalfa frequently differ. Common alfalfa produces a taproot with numerous branch roots of smaller size, and true rhizomes seldom occur, but the crown may become branched several inches beneath the surface of the ground. In the case of yellow-flowered alfalfa, the root system differs greatly from that of common alfalfa. In comparatively few cases is a single taproot developed, while in a majority of cases there is developed a branched rooting system. Abundant rhizomes are produced, and sometimes aerial branches arise from the horizontal roots. The roots of variegated alfalfa have characteristics intermediate between the two previous groups.

Apparently the type of root system is important in the adaptation of alfalfa. Based on the results of observation and investigations, Southworth[7] stated that the ability of alfalfa to resist winter injury depended to a great extent on the root system. Plants that had a branched root system withstood winter heaving much better than those with single taproots.

Uses. Alfalfa is used in many different ways, and it is probable that no other forage crop produced in this country has so many different uses. The crop is high in feeding value and is excellent for general feeding purposes. About 80 per cent of the crop is made into hay. It is also used for pasturage, soiling, silage, and making meal. Alfalfa is a good permanent cover crop and frequently increases the yield of succeeding crops, but it is not valuable as a green-manure crop.

Culture

Seed. In the selection of seed for seeding, it is important to consider the variety, the section of the country where it was produced, and the quality of the seed in regard to purity and germination.

In respect to the purity of alfalfa seed, it is important to secure seed free from weed seeds, especially those which are noxious, such as dodder and Russian knapweed. The other impurities that are likely to occur should receive consideration, and only seed tested for high purity should be planted.

The viability of the seed should be determined by germination tests, and only seed of high viability should be used. Plump seeds of bright olive-green color usually germinate well, whereas shriveled seeds or seeds of brownish color generally germinate poorly.

Climatic and Soil Requirements. The bulk of the alfalfa crop is produced west of the Mississippi, mainly on account of the adaptation of the crop. A dry hot climate is most suitable, but alfalfa will not thrive in hot humid sections. Thus it is found that the crop is mostly grown in the semiarid sections, especially where irrigation is used. Cold relations are also an important factor. A temperature of −31°F. is very injurious to alfalfa. However, the varieties differ in cold resistance.

The soil requirement of the crop is probably next in importance to the climatic relation. Deep soils are necessary for alfalfa on account of the great root development; and good drainage is also essential. Under semiarid conditions, alfalfa seems to thrive on nearly all soils with the exception of those containing much alkaline salts. In the East, where climatic conditions are unfavorable for the growth of alfalfa, the soil conditions must be especially favorable. In that part of the country, for successful results, a deep, fairly productive, well-drained soil, which contains an abundance of lime, is necessary.

Time of Seeding. The time of seeding depends upon several factors, and it therefore varies in the different sections of the country. Late spring or early summer seeding is usually best in the Northwest, whereas in the Southwest the time of seeding ranges from the middle of August in the latitude of Washington, D.C., to October or November along the Gulf Coast. Spring seeding is generally followed in the semiarid sections of the northern Great Plains. In the southern region of this area late summer and early fall seedings are recommended. In the irrigated sections of the Southwest, October is usually the best time of seeding. When alfalfa is seeded in the fall, the seeding should be done so that the plants will secure sufficient growth to endure the winter; it should also be done late enough to escape the summer weeds. In the North, winter-

killing is the great danger to be reckoned with in seeding, but in the South weeds are a great menace.

Methods of Seeding. The methods vary in the different sections of the United States. In regard to the depth of seeding, this varies with the soil. With the proper moisture supply the seeds will germinate satisfactorily at depths up to 2 inches. As a rule, on the heavier kinds of soils, the seeds are covered from ½ to 1 inch. On sandy soils or in the semiarid regions the seeding is deeper, about 1½ inches, to ensure better moisture supply.

The seed may be sown by hand or from the seed attachment of the grain drill; it may be mixed with the fertilizer and sown from the fertilizer compartment of the drill; or various kinds of seed-distributing machines may be used. The object in any case should be to get the work done as cheaply as possible and to secure a uniform distribution of the seed. Williams[8] in Ohio seeded alfalfa at the rates of 5, 10, 15, 20, and 25 pounds per acre, using both the broadcasting method from the seed attachment of a grain drill and the drilling method with a clover drill. The average yield per acre for 2 years for the five different rates of seeding was 8,174 pounds for broadcast seeding and 8,381 pounds for drilling.

Nurse Crops. The use of nurse crops is generally inadvisable. However, in spring seedings, when weeds are likely to be a factor, nurse crops may prove beneficial. In the East, South, and semiarid sections of the West, nurse crops should not be used. In the irrigated sections nurse crops may be planted, but even here the alfalfa usually succeeds in spite of the nurse crop. Spring barley and spring oats, the former more frequently, are generally used for the associated crop where any such crop is used.

Rates of Seeding. The rate of seeding is greater in the East than in the West. In the latter region, under ideal conditions, good results have been obtained from the use of 1 to 5 pounds of seed per acre. Good yields are frequently secured from the use of 5 pounds. However, the rates of seeding are generally greater than these amounts. Oakley and Westover[9] recommend 20 to 25 pounds per acre in the East; under irrigated conditions they recommend 15 to 20 pounds; and under dryland conditions, 8 to 12 pounds.

At the Ohio Experiment Station, Williams[8] secured the following yields from different rates of seeding: 5 pounds of seed, 9,013 pounds of hay to the acre; 10 pounds, 9,148 pounds; 15 pounds, 8,735 pounds; 20 pounds, 8,613 pounds; and 25 pounds, 7,722 pounds. The yields are the average of 3 years from broadcast seeding from the seed attachment of the grain drill. Five pounds of seed gave results quite as satisfactory as the greater amounts, but the weeds were more of a problem. The use of 10 pounds of seed per acre is recommended.

Inoculation. Unless the crop will become naturally nodulated, inoculation should be done artificially at the time of seeding. It is not probable that alfalfa production will be successful unless nodulation is present.

Sears,[10] reporting results from Canada and Illinois and three other states, shows that inoculated alfalfa produced 70.4 pounds more protein per ton of hay than uninoculated alfalfa. Burlison and others[11] give results found in Illinois that show that inoculation practically doubled the yields of alfalfa, compared with those where no inoculation was used.

Harvesting. The proper time for the harvesting of the alfalfa crop has been discussed in Chap. XIV.

Cultivation. In most alfalfa-growing sections the stands have a tendency to become thinner as they become older, and as a result native grasses, especially bluegrass and Bermuda grass, as well as weeds, begin to come in. Cultivation of the alfalfa soon after cutting not only destroys the grasses and weeds to a great extent but seems to invigorate the alfalfa. Cultivation is also effective in controlling grasshoppers, wireworms, army worms, and other insects by exposing their eggs to the cold. Summer and fall cultivations are helpful in disturbing the alfalfa weevil. There are several implements with which the cultivation is done, such as the spring-tooth harrow, alfalfa cultivators, spike-tooth harrow, and the disk harrow. The latter implement should not be used unless the ground is extremely hard. It does not give the good results so often attributed to it.

Pasturing Alfalfa. Alfalfa is an excellent hog pasture, but under certain conditions it causes cattle and sheep to bloat. When grass is sown with the alfalfa in about equal parts, this trouble is reduced to the minimum. A mixture of alfalfa and brome grass for hay and pasture is becoming increasingly popular in some sections of the United States.

In the use of alfalfa as pasture the principle of light grazing should be borne in mind and the number of animals maintained in the field should be consistent with securing two light cuttings of hay per season. Alfalfa should not be grazed the first year after planting, and but lightly the second year. Close grazing for one season will badly injure the crop but proper grazing is not injurious.

In dry regions the danger to animals from bloating and the damage to the crop from close grazing are not nearly so great as in the humid regions.

Seed Crop. The commercial seed crop of alfalfa is mainly grown in the semiarid regions of the West. When seed production is desired under irrigated conditions, the water is withheld from the crop. Seed production is seldom profitable in the humid regions of the country.

Alfalfa requires a dry, hot season for the greatest production of seed, and it is customary to appropriate for seed the crop that will mature in

the driest and hottest part of the season. In the Northern states this is the second crop, but south of Kansas the third crop is generally saved.

The yield of seed varies from season to season, but a yield of 2 to 5 bushels per acre is considered fair, and a yield of 8 bushels is a large crop. The principal seed-producing states are Kansas, Oklahoma, Arizona, Minnesota, Idaho, and Nebraska (1934–1943).

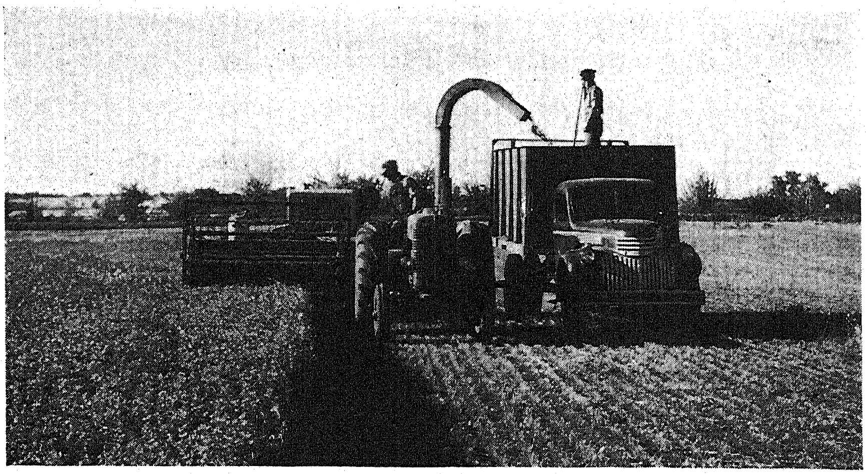

FIG. 57. Loading cut alfalfa into a truck that will haul it to a nearby dehydration plant. This 160-acre field near Topeka, Kansas, was seeded in 1946. In May, 1947, it produced enough to give about 1½ tons of dehydrated alfalfa per acre. (*U.S. Dept. Agr. photograph by Forsythe.*)

The crop, when harvested for seed, should be cut when about three-fourths of the pods are brown and the seeds have become yellow and hardened.

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Topics for Discussion

1. Why is alfalfa the favorite hay crop with dairymen?

2. How does alfalfa compare with clovers as a forage-producing and soil-improving crop in your locality?

3. How many cuttings of hay and what yield per acre can be reasonably expected from alfalfa in your locality?

4. What soil types are best suited to alfalfa, and what are the best sources of seed for your locality?

CHAPTER XXX

SORGHUMS (Sorghum vulgare)

The sorghums are important crops in the United States where the rainfall is insufficient for the production of corn. Most of the sorghum acreage is in regions having a rainfall of 15 to 30 inches annually. Some

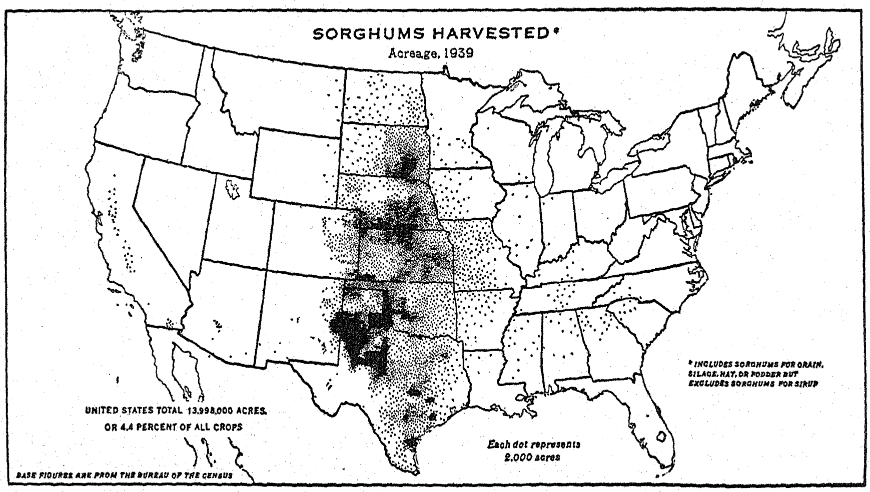

FIG. 58. More than eighty varieties of sorghums and sorgo are now grown commercially in the United States for grain or forage. These varieties differ greatly as to growing season and ability to resist drought. Sorghums grown for forage may be utilized as fodder, stover, silage, or hay; they may be cut and fed green; or used for pasture. These crops are to the Great Plains region what corn is to the Corn Belt and are generally recognized as the basis of a permanent diversified agriculture. In the northern Great Plains area, the seasons are shorter and cooler and the crop is grown mostly for forage, as grain production is too uncertain. Sorghums are used in the semiarid farming districts as a substitute for corn, because of their high yield and drought-resistant qualities. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

of the sorgos, or sweet sorghums, however, are grown for hay and sirup production in sections with higher rainfall.

There are four classes of sorghums commonly grown in the United States: (1) sorgo, or saccharine sorghum; (2) grain sorghum, or non-saccharine sorghum; (3) broomcorn; and (4) grass sorghums. The production, especially of grain sorghum, has increased very rapidly. The net increase of about 78 per cent in the acreage of sorghums between 1929 and 1939 was largely attributed to heavy plantings in the Great

Plains area to replace other feed and forage crops unable to resist the droughts of that period.[1]

World Production. The information is slight in regard to the world production of the sorghums. They are cultivated to a great extent for grain production in Africa and India, where the grain is used for human food. They are also cultivated in northern China, Manchuria, and Chosen (Korea). In Europe the crop is not important. In the United States they are grown for sirup, grain, forage, and the manufacture of brooms.

Production in the United States. There has been a great increase in the production of sorghum in the United States during the 15-year period 1930–1944.[2] The production of grain increased from 37,561,000 bushels to 181,756,000 bushels; silage, from 572,000 tons to 6,358,000 tons; and forage, from 6,326,000 tons to 12,306,000 tons.

The yields of sorghum for grain, forage, and silage for several of the leading states and the United States are presented in Table 21.

TABLE 21. SORGHUMS FOR GRAIN, FORAGE, AND SILAGE

State	Grain			Forage			Silage		
	1933–1942, 1,000 bu.	1943, 1,000 bu.	1944, 1,000 bu.	1933–1942, 1,000 tons	1943, 1,000 tons	1944, 1,000 tons	1933–1942, 1,000 tons	1943, 1,000 tons	1944, 1,000 tons
Texas	33,790	71,817	96,724	3,818	3,725	4,051	1,008	457	789
Kansas	11,189	14,500	49,468	2,433	2,674	3,088	1,685	2,774	3,371
Oklahoma	7,784	5,355	12,915	1,192	1,508	1,717	165	360	550
United States	65,362	103,864	181,756	11,266	10,993	12,306	4,454	4,969	6,358

The states leading in sirup production from sorghum, from 1933 through 1944, are Alabama, Mississippi, Georgia, Tennessee, and Kentucky. These five states produced 60 per cent of the total production of 73,847,000 gallons of sorghum sirup in that 12-year period.[2]

During the 12-year period 1933–1944,[2] broomcorn was produced in the following six states: Oklahoma, 13,987,000 tons; Colorado, 12,217,000 tons; New Mexico, 7,833,000 tons; Illinois, 5,353,000 tons; Texas, 5,217,000 tons; and Kansas, 3,017,000 tons.

Historical. The cultivation of the sorghum plant is very ancient. It was cultivated in ancient Egypt probably as far back as 2,000 years before the Christian Era. Sorghum probably originated in Africa but may have had an independent origin in both Africa and India. The

crop evidently was not introduced into Europe until about 60 A.D. Sorghum, therefore, like the corn plant, is of tropical origin.

The date of introduction of the sorghums into the United States is not definitely known, but, with the exception of broomcorn, the sorghum crop was not important in the United States before the middle of the last century. The permanent introduction of the crop may be traced to that grown by William R. Prince, of Flushing, Long Island, New York, in 1853. It was apparently tried at various times previous to this date. In 1928 there were 4,311,000 acres grown for grain, 4,116,000 acres for fodder and forage, 349,000 acres for sirup, and 298,000 acres for broomcorn.

The sorghum plant is said to have been derived from *Andropogon halepensis*, which is known in the United States as "Johnson grass." However, it has been pointed out that the wild sorghum types separate into two groups: One group includes the perennials, which have rootstocks like Johnson grass; the other includes the annuals, such as Sudan grass and Tunis grass, which do not have rootstocks. The wild annual forms cross readily with sorghum; the wild perennials cross with sorghum only with difficulty. It may be, therefore, that the original prototype of the cultivated sorghums was among the wild annual forms of *Andropogon sorghum*.

Drought Resistance. The adaptation of sorghums, especially the grain types, to dry climates is well known; the reason for such an adaptation is less well known. Miller[3] has shown that sorghums have twice as many secondary roots per unit of primary root as corn, although the number of primary roots is the same. This fact may allow the sorghums to be more efficient in water absorption. Corn is not well suited to semiarid conditions. It has also been shown that the water requirement of the sorghum plant is approximately the same as for corn. Miller[3] has shown that sorghum, as compared with corn, has only half as much leaf area exposed for evaporation. Sorghums, therefore, are apparently less efficient in use of water on the basis of leaf area exposed. However, the sorghums, unlike corn, seem to have the ability to become practically dormant during periods of severe droughts and to renew growth, without much apparent injury, when conditions become more favorable.

Effect on Land. Sorghums are supposed to be "hard on the land." The effect, however, seems to be only temporary and is most noticeable on the crop that immediately succeeds the sorghum crop, as fall-sown grains, and usually is not apparent on the crop seeded the following spring. The difference in yield of a crop following sorghum as compared to one not following sorghum is usually 15 per cent less. However, since sorghums grow until frost, they often leave the soil depleted in moisture and in readily available plant nutrients. There is also a possibility of a

temporary tie-up of available nitrogen by the microorganisms during the process of root and stubble decay.

Sorghum Poisoning. Numerous cases are recorded where cattle have been poisoned from feeding on growing sorghum plants, of both sweet and grain types. The injury is caused by prussic acid, which forms while the sorghum is being digested in the stomach of the animals. Cases of poisoning are more numerous when the sorghum that is eaten has been stunted by hot dry weather. It seems that cutting the plants and allowing them to wilt eliminates the danger of poisoning. It is evident that it is inadvisable to pasture stunted sorghum plants. When such plants are made into cured forage or silage, the trouble from poisoning does not ordinarily develop.

Composition. Analyses of samples of four grain sorghums made at Amarillo, Texas, in the period 1908–1912, revealed that they contained 13 per cent crude protein, whereas corn contained only 9.3 per cent.

SORGOS

The sorgos, or sweet sorghums, being high in sugar, have a juicy pith and produce but a small amount of grain as compared with the grain sorghums. From their permanent introduction in 1853 into the United States until 1880 their chief use was for sirup, but since the latter date they have been grown primarily for forage.

Varieties. According to Martin,[4] the principal varieties of sorgo (sweet sorghum) grown for forage are Sumac, Black Amber, Orange, Honey, Atlas, and Gooseneck. The grain sorghums most valuable for forage are Hegari and the Blackhull, Red, Pink, and Dwarf kafirs.

Culture

Seed. The selection of good seed of high-yielding adapted varieties is just as important with sorgos as with other crops. There is a considerable difference in the time of maturity, height of growth, and yielding ability of certain varieties. The differences are worthy of careful consideration. Since sorgos cross readily, it is sometimes difficult to secure pure varieties. Special attention should be given to the selection of varieties that have not become intermixed, or to the separation of the mixtures by roguing.

In addition to the selection of seeds, the storage of the seeds should be given attention. The seeds are sometimes harvested when somewhat immature, but these will germinate well if stored where they can dry at once. Either improper storing of immature or damp seeds, or allowing them to become subjected to freezing weather before drying, is likely to result in greatly reduced germination.

Time of Seeding. Sorgos are more sensitive to cold than corn, and for this reason the seeding is usually begun after corn planting is finished. As a rule, seeding starts from 2 to 4 weeks after the earliest corn is planted. Seeding may be delayed much later if the length of the growing season will allow. According to Martin,[4] the crop should be planted as early as climatic and soil conditions permit, usually early in March in the southern part of the sorghum region where there is danger of injury to the grain by the sorghum midge. A safe rule in all localities, except where the sorghum midge is troublesome, is to plant not earlier than about 2 weeks after corn-planting time.

Method of Seeding. According to Martin,[4] approximately 85 per cent of the sorghum crop is seeded in rows sufficiently far apart to cultivate with the ordinary corn-cultivating implements. The broadcast method of seeding is followed to a great extent when the crop is to be used for hay. Even when used for hay, there is little, if any, difference in yield, but the stalks are smaller and the hay of somewhat better quality when the crop is broadcast. For planting in rows, two general methods are followed: surface planting and listing (or planting in furrows). The first method is best suited to regions of moderate rainfall, and the latter to dry regions (Martin[4]).

Rate of Seeding. The amount of seed required to seed an acre will be less if the crop is seeded in rows than if broadcast. Martin[4] states that the largest forage yields are obtained when the plants are spaced about 2 to 4 inches in the rows. If grain sorghums are grown for forage, a 6- to 8-inch spacing is recommended. In the Great Plains region the proper amount to use is approximately 4 to 6 pounds of seed to the acre. In the dry regions it is seldom advisable to use more than 4 pounds of seed per acre. Where the rainfall is more plentiful, 35 to 40 inches, the quantity of seed used per acre is usually 6 to 8 pounds.

In seeding broadcast or drilling, farmers generally use a rate of seeding of from 45 to 60 pounds of seed per acre. Martin[4] states that in Kansas and Texas there was but little difference in yield from seeding at rates varying from 15 to 75 pounds per acre. The smaller rates of seeding produce a coarser growth, and there is more likelihood of trouble from weeds. The quantity recommended west of the one-hundredth meridian in the Great Plains is 30 pounds of seed per acre; 45 pounds between the ninety-eighth and one-hundredth meridians; and 60 to 75 pounds east of the ninety-eighth meridian.

Depth of Seeding. The seedlings of sorgo are not so vigorous as those of corn and the other cereals. The seeds should be covered deep enough to secure sufficient moisture for germination. The depth will therefore depend on the kind of soil and the amount of moisture present at

seeding time. The usual depth of seeding is from 1 to 2 inches. On the wet, heavy types of soil, the right depth of seeding is about 1 inch, whereas on sandy soils the seed may be placed 2 inches deep and sometimes deeper with good results.

Cultivation. The early growth of sorghum is slow, and the young plants therefore require care to prevent their being crowded out by weeds. Where the field has been plowed late in the spring and then surface-planted, a common practice is to cultivate once with a spike-tooth harrow soon after the sorghum has emerged and later with an ordinary shovel cultivator, as may be necessary to control weeds. In other words, the crop is handled much the same as corn in the same area.

Listed sorghum is usually cultivated with special disk and knife cultivators, some of which handle two or more rows at a time (Martin[4]).

Harvesting. Where the crop is to be used for forage, the plants should be fairly mature when harvested. At this stage of growth the greatest amount of dry matter is produced, the feed is more palatable, the danger from poisoning is less, the loss in weight and quality during curing is reduced, and silage made from mature sorgo is of better quality than that made from sorgo when too immature.

The most efficient machine for harvesting sorghum in rows is a corn or row binder. A farmer, assisted by two men to shock the bundles, can harvest 6 to 7 acres per day. When once carefully shocked, sorghum keeps in good condition until late in the winter and can be hauled to the barnyard to be fed or stacked whenever other work is not pressing. A long period for curing in the shock is necessary in the production of good sorghum fodder. When the crop is intended for silage a row (corn) binder ordinarily is used.

Broadcast or drilled sorgo is usually harvested as a hay crop with a mower. It is best to allow the crop to lie in the swath for a day or two, then rake into windrows, and leave at least 4 days, or longer if the weather is not favorable for curing. As soon as the leaves are fairly dry the hay may be placed in cocks to complete the curing process (Martin[4]).

Sorghum for Sirup. Sorgo when harvested for sirup production should be in the hard dough stage, as the sugar content increases until maturity.

If the crop is to be utilized for sirup, the leaves should be stripped and the heads removed before pressing, and this work is usually done before the plants are harvested. In warm weather, to prevent fermentation, the juices should be removed within a day or two after cutting. Frosted sorgo should be cut at once and put in stacks. The leaves and heads should not be removed until just before the juice is to be extracted.

The amount of sirup produced per acre will depend on the kind of

sorgo planted, stage of development when cut, kind of mill used, and the care exercised in manufacture. The yield usually varies from 60 to 300 gallons of sirup per acre, the average for the United States being 77.8 gallons in 1928. Assuming an acre yield of 12 tons of stripped stalks and a 75 per cent extraction of juices having a density of 10 degrees, it may be determined that approximately 375 gallons of sirup, having a density of 40 degrees, would be obtained (Cowgill[5]).

FIG. 59. Combining a field of dwarf sorghum at Lubbock, Texas. This 200-acre field is yielding 60 bushels per acre of grain sorghum. (*Courtesy of R. E. Karper, agronomist in sorghum investigations.*)

GRAIN SORGHUMS

The nonsaccharine sorghums are commonly called grain sorghums, since their principal use is for the production of grain, although they are also used for rough forage. They are very resistant to droughty conditions and thrive exceedingly well under such conditions as compared with the other crops commonly grown for grain.

Groups and Varieties. Martin and Cole[6] state that more than forty distinct varieties of grain sorghums are now grown in the United States. Many of the older, well-known varieties are grouped as kafir, milo, feterita, durra, hegari, shallu, and kaoliang, but in addition there are several miscellaneous varieties of hybrid origin, including darso, shrock, freed, white yolo, chiltex, and premo, which do not permit of easy classification.

The varieties differ in time of maturity; height; juiciness of stalk; size and color of grain; leafiness; color of chaff; beardedness, shape, and compactness of heads; and many other characters. Some varieties normally

reach heights of more than 6 feet, but extra-dwarf varieties grown for harvesting with combines usually do not exceed $2\frac{1}{2}$ feet in height.

According to Martin,[7] tailor-made new varieties of sorghums that can be combined have been developed. Such developments save seven-eighths of the man-hours needed to harvest the grain by hand and thresh it later.

Martin[7] names six varieties that have been distributed since 1940 and were grown on 7 million acres by 1944. These varieties are Martin, Plainsman, Westland, Midland, Caprock, and Bonita. They comprise 80 per cent of the sorghums harvested for grain in the United States.

Uses. The main reason for growing grain sorghums is for the grain. However, a considerable amount, especially kafir and hegari, is harvested and fed as "bundle feed," and some is made into silage. The grain has about nine-tenths the feeding value of corn, and the crop is grown in those sections too dry for profitable corn production. The grain is used mostly for feed, a little for human food, and for making alcohol.

Culture

Seed. The choice of adapted varieties is important in the case of the grain sorghums. It is advisable to select pure seeds that will germinate well and are true to type. Head-selected seeds are preferable to seeds selected otherwise. In making the head selections, one should consider uniformity in height, uniformity of heads in size and shape, and uniformity in ripening as well as productiveness.

The seed heads should be stored in such a way as to maintain the vitality of the seeds, and the seeds, after threshing, should be thoroughly cleaned and tested for germination.

Time of Seeding. For best results the grain sorghums, which are hot-weather plants, should not be seeded too early. They should be seeded from 10 days to 2 weeks after the ordinary time of planting corn.

Sorghums appear to reach a better final development when permitted to make rapid continuous growth throughout the period from planting to maturity without being checked or delayed by adverse weather. Early plantings may cause the crop to come into head during midsummer when the temperatures, combined with dry weather, frequently check the growth. It has been observed that under most conditions, both in the Great Plains and in the irrigated sections of the Southwest, a better yield is likely to be obtained if the time of planting is such that the plants come into head after the period of midsummer heat rather than during this period (Martin and Cole[6]).

Rate and Method of Seeding. The seeding is usually made in rows about $3\frac{1}{2}$ feet apart. The space between plants in the row varies

largely with varieties. Since it hastens maturity, narrow spacing of all varieties is beneficial when sorghum midge is present. In rows from 40 to 44 inches apart, kafir is usually planted about 6 inches in the row, as are also hegari, darso, and schrock varieties. Milo produces the best average yields when the plants are spaced 1 to 2 feet apart in the row. The seeds of feterita are planted 6 to 12 inches in the row. The dwarf varieties are usually seeded about 6 inches apart in the row.

The amount of seed required to plant an acre will vary with the spacings. Under favorable conditions it will require on the average 3 to 4 pounds of clean viable seeds to plant an acre. The purpose for which the crop is grown will also affect the quantity of seed required. In dry regions less seed should be sown than in regions of more abundant rainfall.

The crop is usually seeded with corn-planting machinery, plates being used to suit the sorghum seeds. In regions of very low rainfall, the crop is often listed instead of being surface planted. The latter method is recommended where it can be followed.

The methods of cultivating grain sorghums depend to some extent upon whether the crop is planted with a surface planter or with a lister, but they usually are the same as for corn in any particular locality.

Irrigation. Nearly the entire grain sorghum crop of Arizona, most of that in California, and some of that in Colorado, New Mexico, Kansas, and Texas are grown under irrigation.

When growing grain sorghums under irrigation, the land is usually irrigated before being prepared or after plowing. As soon as the soil is dry enough it is plowed and harrowed or simply harrowed, and the crop is planted immediately. After the crop is up, the land is irrigated often enough to maintain a supply of soil moisture, provided water is available at not too great an expense. The usual number of irrigations varies from one to three, depending on climatic conditions, supply of water, and texture of soil (Martin and Cole[6]).

Harvesting. Where the crop is harvested for grain production, the plants should be allowed to become fully ripe before harvesting. The varieties that shatter badly may be cut when they are somewhat immature. In case the crop is to be utilized for silage, harvesting should take place when the seeds are in the hard dough stage.

The plants are usually harvested by one of four methods: (1) heading by hand, (2) heading with a grain header, (3) cutting with corn binder, or (4) harvesting with a combine. When the crop is harvested with a corn binder it is shocked like corn. When the combine is not used the grain may be removed from the heads by running them through the ordinary threshing machine.

Dwarf varieties are easy to harvest with a combine, and this method is very economical. Cracking of grains should be avoided.

BROOMCORN

Broomcorn is of little value for forage, but the matured seeds are often used for poultry and stock food. The crop is grown almost entirely for the elongated branches of the panicle, which are used for the manufacture of brooms.

FIG. 60. Grain sorghum being harvested with a two-row binder on a contour, terraced field in Wilbarger County, Texas. The estimated yield is 1,500 pounds per acre. (*U.S. Dept. Agr. Soil Conserv. Serv. photograph by Jenkins.*)

Varieties or types. Martin and Washburn[8] state that the varieties of broomcorn grown in the United States may be divided into three groups: standard, western dwarf, and whisk dwarf.

Standard broomcorn usually grows to a height of 7 to 15 feet. It bears a brush from 16 to 24 inches or more in length. Evergreen, Black Spanish, and California Golden are varieties of this group.

Western dwarf broomcorn usually attains a height of from 4 to 7 feet. The brush length is from 15 to 24 inches. Evergreen dwarf, Scarborough, and Black Spanish Dwarf are varieties of this group.

Whisk dwarf broomcorn usually grows to a height of 2½ to 4 feet and produces a fine slender brush about 12 to 18 inches in length. Japanese Dwarf is the only variety of this group.

Production. Broomcorn may be produced satisfactorily wherever corn does well. Since the quality of the brush is as important as the yield, climatic conditions must be favorable, and the soil must be uniform

in productiveness. Care should be taken to secure good seeds; it will usually require from 2 to 4 pounds to sow an acre when planted in rows 3 to 3½ feet apart. Broomcorn is generally seeded 2 to 3 weeks after corn planting, in rows about 3½ feet apart. The plants are spaced about 3 inches apart in humid sections and 6 to 9 inches apart in sections of limited rainfall. A uniform stand is important as this will determine to some extent whether the brushes will be uniform.

The brush should be harvested when the natural green color extends from the tip of the fiber to the base and center of the head. This stage will be from the time the flowers are falling to the time of the milk or early dough stage of the seeds. The methods of harvesting Standard and Dwarf broomcorns are different. The Standard broomcorn is bent over or tabled and the brush is cut off, while the Dwarf is jerked or pulled from the standing stalks.

After harvest the brush is taken to the drying shed where the brush of poor quality sometimes is separated from that of good quality. The crop is then threshed and placed under shelter to cure. Rapid curing is necessary in order to maintain the desirable green color. The brushes are then made into bales weighing from 300 to 400 pounds each, and stored in a dry dark place until ready to market.

GRASS SORGHUMS

The grass sorghums include several grasses, chief among them being Sudan grass and Tunis grass. Sudan grass is by far the most important grass sorghum, and the discussion of the group will be confined to it.

Sweet Sudan grass is a cross between a saccharine sorghum and Sudan grass. It is more palatable, has broader leaves, larger stems, and taller growth than ordinary Sudan grass. It also matures later.

Historical. Sudan grass (*Sorghum sudanensis*) was introduced into the United States from Khartoum, Sudan, in 1909 through the efforts of C. V. Piper, of the Office of Forage Crops and Diseases, U.S. Department of Agriculture. It is probably a native of Upper Sudan, where it is called "garawi." Sudan grass was immediately successful in the United States. From the 8 ounces of seed obtained in the original importation a crop was developed that in 1918 was worth $10,500,000.

Description. Sudan grass is an annual hay plant belonging to the sorghum family. The stems are slender and average 3 to 5 feet in height when the crop is planted broadcast or drilled, and 6 to 8 feet when grown in rows. The plants have numerous rather soft leaves, loose, open panicles, numerous tillers, rarely any branches, and no rootstocks. It may be said that it is not unusual for a single plant to bear as many as

50 tillers. The production of tillers is most apparent after the first cutting and as a result the hay of the second cutting is of finer texture than that from the first. Sudan grass closely resembles Johnson grass, but the latter is a perennial. Under favorable conditions Johnson grass grows from 3 to 4 feet in height and has few, narrow, rather harsh leaves with thick white midribs. The panicles are loose, open, and often drooping, there are but few tillers, and there are numerous aggressive rootstocks that make the plants difficult to eradicate.

Sudan grass, which has been classed as a "grass sorghum" because of its absence of rootstocks, is probably a near relative of the cultivated sorghums and crosses readily with them.

Adaptation. Sudan grass, like the other sorghums, thrives best in a warm climate, and, under favorable conditions, as many as four cuttings may be obtained in one year. In drought resistance it is equal but not superior to the best sorghums, but it does best when abundant moisture is present.

Sudan grass is not exacting in its soil requirements, but of course thrives best on a rich soil. It may be said that Sudan grass does better on poor soils than most hay crops. The crop is as tolerant of acid and alkali soils as the other sorghums. Well-drained soils are essential, as cold wet soils often result in failures.

Uses. Sudan grass makes a hay of excellent quality, and the yields are good. Southward from the central part of the United States, two cuttings may be secured, and sometimes as many as four. The first cutting is usually produced in from 60 to 80 days after seeding, the second cutting is usually ready in about 45 days after the first one, and the third one requires 50 to 55 days after the second. Sudan grass makes a rapid growth and therefore is adapted for use as a catch crop. Its chief competitors as a forage plant are sorgo and millet. The comparative yields of these crops as reported by Vinall and Getty[9] are shown in Table 22.

TABLE 22. COMPARATIVE YIELDS OF SUDAN GRASS, MILLET, AND SORGO, SEEDED BROADCAST OR IN CLOSE DRILLS

Location of test	Yield of cured hay per acre, tons		
	Sudan grass	Millet	Sorgo
Southern Great Plains	3.33	1.83	4.64
Central Great Plains	1.78	1.51	2.89
Northern Great Plains	1.49	1.89	2.24
Timothy and clover region	2.80	2.52	6.06

Sudan grass is also valuable for soiling, silage, and summer pasturage. Like Johnson grass, it is less likely than the larger sorghums to contain a sufficient amount of prussic acid to be dangerous. Sudan grass has also been seeded in mixture with cowpeas and with soybeans.

Feeding Value. Chemical analyses of Sudan grass show that it has about the same composition as common foxtail millet and timothy.

Culture

Time of Seeding. Sudan grass should not be seeded until the soil is warm; *i.e.*, about 2 weeks after the normal date for planting corn. When the crop is seeded too soon, the early growth is usually slow and the stand is poor. In the extreme South the best time of seeding is between Apr. 1 and May 1; in the latitudes for Oklahoma and Kansas, between May 1 and June 15; and in the latitudes for Nebraska and South Dakota, between May 15 and June 15. From Kansas south, good yields of hay may be secured by seeding July 1 or even later.

Vinall and Getty[9] report the results of tests as shown in Table 23. The tests in the southern section were conducted in California, Texas, Louisiana, Mississippi, Georgia, and Florida; in the middle section they were conducted in Kansas, Oklahoma, Texas, Tennessee, Virginia, and Maryland; and in the northern section they were conducted in Minnesota and South Dakota.

TABLE 23. AVERAGE YIELDS OF SUDAN GRASS HAY FROM DIFFERENT DATES OF SEEDING IN VARIOUS PARTS OF THE UNITED STATES

Location of test	Average yields of cured hay (tons) per acre from plantings made on							
	Apr. 1	Apr. 15	May 1	May 15	June 1	June 15	July 1	July 15
Southern section.	3.21	3.18	2.83	2.76	2.69	2.32	1.83	1.33
Middle section...	1.14	1.45	2.15	2.27	2.28	2.20	1.66	1.35
Northern section.	....	....	3.75	3.71	3.82	3.63		

Method of Seeding. Sudan grass may be drilled or sown in rows of convenient widths. The latter method is often followed under dry farming conditions, whereas, under humid conditions and under conditions of irrigation, drilling is practiced, especially when the crop is intended for hay. A hay of better quality, because of the smaller stems, is usually secured from drilling rather than from seeding in rows. For seed production the crop is generally seeded in rows.

Rate of Seeding. Sudan grass has been seeded at rates varying from 10 to 40 pounds per acre. The best rate of seeding, however, cannot be definitely stated, since the plants tiller very profusely, especially when

the stands are thin. The rate generally recommended for drilled or broadcast seedings under humid conditions is 20 to 25 pounds per acre; under irrigation, 15 to 20 pounds; and in dry sections without irrigation, 12 to 15 pounds. If the ordinary grain drill is set to sow 2 pecks of wheat per acre, about 20 to 25 pounds of Sudan grass seed will be sown.

For seeding in cultivated rows 36 to 44 inches apart, the quantity of seed required will be 2 to 4 pounds per acre, while in 18- to 24-inch rows, 4 to 6 pounds of seed per acre will be necessary.

Harvesting. The preferable time for cutting Sudan grass for hay is from the time the plants begin to head until they are fully headed. If several cuttings are desired, harvesting is done slightly sooner than if a subsequent cutting is not desired. On account of the numerous tillers that mature considerably later than the primary stem, Sudan grass does not deteriorate so much as many other grasses from late cutting. When the crop is to be used for seed, it is cut with the ordinary grain binder when the seeds are about mature and then allowed to cure in shocks.

Seed Production. Under dry conditions when the crop is not irrigated and under humid conditions the yield of seed is greater when the crop is grown in cultivated rows. Under irrigation, however, the yield of seed is greater when the crop is broadcast or seeded in close drilled rows.

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Topics for Discussion

1. What are the chief drawbacks to increasing the acreage of sirup sorghums in the United States?

2. Grain sorghums yield more grain in certain sections of the East than they do in the Southwest. Why have they not been successfully introduced into these eastern areas?

3. Under what conditions are sorghums dangerous as forage for livestock?

4. Are sorghums desirable for silage where the season is well adapted to the production of corn? Why?

CHAPTER XXXI

MISCELLANEOUS FORAGE AND SEED CROPS

Most of the hay and pasture acreage of the United States is composed of perennials. However, a large acreage is grown with annual forage plants. Four of these annual forage plants together with two annual seed plants will be considered in this chapter.

MILLETS

Origin and History. The earliest cultivation of the millets is prehistoric. They were used by the lake dwellers of Switzerland in the Stone Age and as early as 2700 B.C. by the Chinese in a religious ceremony. The millets, which are native to southern Asia, spread to Europe in ancient times. In 1889 more than 74 per cent of the acreage of millet was in the North Central states, and Kansas was the leading state, having 349,906 acres. In 1909 the leading states were Kansas, Missouri, Texas, Nebraska, North Dakota, Tennessee, and Oklahoma. It may be said that the acreage seeded to millet decreased from 1,743,887 acres in 1899 to 1,117,769 acres in 1909.

Foxtail Millet (*Chaetochloa italica*). The foxtail group is the principal one and constitutes 90 per cent or more of the millet acreage in the United States. The chief varieties of the group are Common, Golden or German, Hungarian, Gold Mine, Kursk, and Turkestan.

Foxtail millet, like other millets, requires warm weather during the growing season; where cool weather prevails during the summer, the crop does not thrive. However, in the northern Great Plains, where the summers are short but hot, millet is extensively grown. Fairly abundant rainfall is necessary, as the crop does not revive after a drought as does sorghum; it may be said that millet has a low water requirement.

The crop does best on rich, well-drained soils high in organic matter. It has the reputation of being "hard on the land," but it is doubtful whether this report is true to any greater extent with foxtail millet than with other crops producing a similar yield in the same period of time. Even if there is any justification for this opinion regarding the effect of foxtail millet on land, farmers seldom fail to plant on this account.

The crop should not be seeded until danger of frost is over, and planting is usually not started until 2 or 3 weeks after corn is ordinarily planted.

Since the crop is quick growing and thrives best in hot weather, it is frequently used as a catch crop and may be planted any time during the summer. However, the last date of seeding should allow 60 to 70 days before frost. The crop is usually sown broadcast with the grain drill at rates varying from 2 to 4 pecks per acre.

Foxtail millet is used mainly for hay, and it has about the same feeding value as timothy hay. The hay is slightly laxative to horses and when fed for a long time may cause increased action of the kidneys and slight swelling and inflammation of the joints. Apparently the hay does not have these effects on cattle and sheep.

Proso Millet (*Panicum miliaceum*). Proso is often called "hog millet" because of its frequent use as hog feed. According to Martin,[1] proso is an early-maturing millet, the seed of which is used for grain. It is best adapted to the northern prairie and Great Plains sections of the United States, where it is grown to a limited extent as a late-sown catch crop.

Proso produces fair yields of seed with a limited supply of moisture but cannot withstand severe drought. Other grains usually yield more than proso, but they must be sown earlier.

Proso should be sown with a grain drill at the rate of 2 to 3 pecks per acre, from 2 to 4 weeks after corn-planting time. It will usually mature seed if sown in July. It is harvested and threshed like other small grains. In the United States proso is used chiefly for birdseed, poultry, and stock feed.

VETCHES (Vicia spp.)

Kinds. There are a number of kinds or species of vetches; more than 120 have been recognized. However, there are two species mainly grown in the United States: hairy vetch (*Vicia villosa*), also called "winter vetch" and "sand vetch," and common vetch (*Vicia sativa*), also called "Oregon vetch" and "spring vetch."

McKee[2] describes a new legume for the South known as "Big-flower" vetch. He states that it has proved its worth in experimental tests, and growers have made commercial plantings of it. When once established, it persists without further cost for seed, and because it makes good winter growth it is a promising winter cover crop for soil improvement. High cost of seed is of minor importance when one considers that when vetch is once established it will last 5 years or more.

Common Vetch. Common vetch is an annual. It is seeded in the fall in sections having mild winters and in the spring in regions where the winters are severe. The winter strains will usually withstand a temperature of 10°F., but zero temperature results in much damage. On the

Pacific Coast and in the South, fall seeding is practiced; in the other sections spring seeding is preferable.

Adaptation. Common vetch requires a cool growing season, and hot summer weather is injurious. Well-drained soils are necessary, and good soils are preferred, but fair growth is made on the poorer soils.

Culture and Uses. The crop may be sown broadcast or drilled, but the latter is probably the better method. When vetch is seeded alone, the rate of seeding is about 60 pounds (1 bushel) of seed per acre, and the crop is usually seeded for green-manuring purposes. When the crop is sown for hay, a mixture containing vetch and some small grain, frequently oats, is used. In such case, the rate of seeding varies from 30 to 60 pounds of vetch seed with equal weight of oats. Vetch also makes an excellent winter pasture.

Hairy Vetch. Hairy vetch, a winter annual or biennial, differs agriculturally from common vetch in being more hardy and in acting as a biennial when seeded in the spring.

Adaptation. The cold resistance of hairy vetch is shown by the fact that it seldom winterkills in the northern part of the United States or in southern Canada. It is adapted to cool temperate climates and does not do well under hot summer temperature. The crop is drought resistant and especially suited to sandy or sandy loam soils, but it grows well on nearly all productive soils.

Culture and Uses. The seeds may be sown broadcast or drilled, but the latter method is usually preferable. When hairy vetch is seeded alone, the rate of seeding varies from 40 to 60 pounds per acre. However, the crop is usually sown with a small-grain crop, such as rye. In a case of this kind, the small grain is seeded at the ordinary rate, and the vetch sown at the rate of 20 to 30 pounds per acre. The crop is used for hay, green manure, pasture, and silage.

RAPE (Brassica napus)

Origin and History. Rape is a native of temperate Europe, and the wild form is an annual plant. The cultivated plants, however, are either annual or biennial. The annual sort is grown only for the seed, from which oil is obtained. The biennial kind is grown chiefly for forage.

Varieties. The biennial form, of which there are several varieties, is the one largely grown in this country, the Dwarf Essex being the principal variety. Another variety is the Victoria or Dwarf Victoria rape, a variety that at best is not superior to Dwarf Essex. The biennial type lives through the winter under such mild climates as we find on the Pacific

Coast and in the South; under more severe climates it is killed by late fall frosts.

Adaptation. Rape is best adapted to cool, moist climates such as prevail in the northern part of the United States. However, by seeding so that the crop will be largely produced in the cooler portion of the growing season, farmers can grow this crop successfully in other sections of the country.

Rape does not give large yields on poor soils. For high yield, rich moist soils are necessary. The crop is a gross feeder and can be well grown on recently drained swamplands and newly cleared woodlands.

Rather[3] states that rape is almost as high in protein on a dry-matter basis as alfalfa, but the latter is considered the more valuable pasture because of a slightly superior feeding value and because of its beneficial effect on the soil. Hogs, especially white ones or those with thin hair, sometimes sun-scald on rape pasture when they get wet from the dew or rain on the rape leaves and then are exposed to bright sunlight. If dairy cows are pastured on rape just before milking time, the milk is likely to be off-flavored.

Rather[3] further states that the yield of rape is greatly reduced if the crop is pastured so that all the leaves are removed. There should be an abundance of leaf growth at all times.

Culture

Methods and Rates of Seeding. Rape may be sown in cultivated rows; it may be drilled; it may be sown broadcast; and it may be sown in mixtures with some other crop, such as oats. When seeded in cultivated rows, the crop is usually seeded at the rate of 2 or 3 pounds of seed per acre in rows 24 to 28 inches apart. In case the seeds are drilled, the rate of seeding is 4 to 6 pounds per acre with the same or a slightly higher rate for broadcast seeding. In seeding with small grain, one should generally use 3 to 5 pounds of seed per acre. The method of seeding in cultivated rows is usually followed when the crop is "hogged-off."

Time of Seeding. As a rule, the crop is ready to be grazed in from 10 to 12 weeks after seeding. The time of seeding will vary with the locality, but in any section the crop is seeded to utilize the cooler portion of the growing season. The crop is, therefore, generally sown in the early spring or late summer. In general the seeding in the Northern states varies from May 1 to the last of July. In the South the crop may be seeded in September or October.

Uses. Rape is an excellent pasture crop for hogs and sheep and is also used for pasturing cattle. In case of sheep and cattle, however, there is danger of bloating. Rape is used to some extent as a soiling crop.

SUNFLOWERS (Helianthus annuus)

Origin and History. The sunflower is a native of the Great Plains region from Nebraska to northern Mexico, where the wild forms frequently occupy large areas. Its natural range extends to Peru, and sometimes it is stated that the sunflower is also a native of Peru. This statement, however, is probably an error. The sunflower was one of the food plants of the American Indian and was cultivated in Spain as early as 1597. The sunflowers cultivated in Europe were no doubt derived from plants developed by the American Indian.

The sunflower is now grown throughout North America. It is also found in South America, especially along the western coast from Colombia to Chile. The crop is grown to a limited extent in Australia, New Zealand, South Africa, Egypt, the Mediterranean region of Europe, India, and China. The sunflower has reached its greatest usefulness in Russia and Hungary, especially in the former country.

Description. The sunflower is an annual with a stout, erect, usually simple stem 1 to 3 inches in diameter and 5 to 20 feet in height; the stem becomes woody. The sunflower has alternate ovate leaves and one to six or more half-nodding heads with a brown or nearly black disk; it also has many golden-yellow rays, frequently 40 to 80. The sunflower that is used to the greatest extent agriculturally has a single large head that is commonly 6 to 12 inches in diameter.

Adaptation. Sunflowers can be successfully grown in almost any part of the United States. However, the crop is not widely grown where other crops that will serve the same purposes do well. In the central and southern Great Plains the sorghums are superior silage plants, and in the Corn Belt corn surpasses the sunflower. In the Southeastern states sunflowers cannot compete with corn, sorghum, Japanese cane, and millet.

Sunflowers do comparatively well where the altitudes are high and where the temperature is relatively low during the growing season. Thus in the high altitudes of the Western states, sunflowers are important since corn, sorghum, and other crops do not produce so large a yield of silage. Sunflowers are much more resistant to frost than corn, and for this reason the sunflower crop may become of great importance in the New England states, northern New York, Michigan, Wisconsin, Minnesota, North Dakota, Montana, Washington, Oregon, and some of the high valleys of the Rocky Mountain region.

The highest yields of sunflowers are secured when the crop is grown on rich soils, but fair results have been secured on the poorer soils. However, no definite information can be given in the matter of yield other than to say that sunflowers will thrive wherever corn does well.

Uses. In Russia the seeds of the sunflower are used extensively for food. In the United States the seeds are used chiefly for poultry feed, and the entire plants, especially in recent years, are widely used for making silage.

Culture. The chief variety of sunflower grown in this country is the Mammoth Russian. The time of seeding will of course vary, but the tests conducted in the various parts of the United States indicate that sunflowers should be seeded about the time corn is usually planted.

The crop may be planted with the ordinary corn planter in much the same way that corn is planted, or one may use the ordinary grain drill by stopping a certain number of holes or feeds in the drill box to give the proper distance between rows. The rows are usually 28 to 36 inches apart and the plants spaced about a foot apart in the row. For seeding in this manner a rate of 6 to 8 pounds of seed per acre is necessary. The crop is cultivated and harvested in the same way as corn.

Yields. Vinall[4] reports yields of 31 to 37.6 tons of sunflower silage per acre at Huntley, Montana; at Bozeman, Montana, the yield varied from 33.6 to 44.1 tons per acre. However, the yields will vary with conditions. For example, at the Washington Experiment Station the 2-year average yield of sunflower silage was 11.59 tons (Schafer and Westley).[5]

The yield of sunflower seed varies greatly, and yields ranging from 13 to 75 bushels to the acre are often reported.

BUCKWHEAT (*Fagopyrum esculentum*)

Buckwheat is one of the less important grain crops grown in the United States. According to Quisenberry and Taylor,[6] for each bushel of buckwheat produced, there is produced about 300 bushels of corn, 150 bushels of oats, 100 bushels of wheat, 35 bushels of barley, and 5 bushels of rye.

Production in the United States. During the 12-year period 1933–1944,[7] Pennsylvania produced an average of 2,473,000 bushels of buckwheat, and New York produced 2,442,000 bushels. Each of these two states produced approximately one-third of the entire production of 7,350,000 bushels.

Origin and History. The cultivation of buckwheat is not thought to be very ancient. It has been cultivated in China for 1,000 years and was introduced into Europe from northern Asia early in the sixteenth century. The crop was unknown to the ancient Greeks, Romans, and Egyptians. Buckwheat was introduced early into the American colonies, for in 1626 samples of the American crop were sent to Holland. It probably originated in central Asia.

Varieties. There are three varieties of buckwheat commonly grown in this country, all of which belong to the *Fagopyrum esculentum* species. These varieties are Japanese, Silverhull, and Common Gray. It is not an uncommon practice for growers to mix the seeds of the first two varieties for sowing.

Description. Buckwheat is a member of the *Polygonaceae* family. However, since the seeds are used for the same purposes as the true cereals, it is often erroneously considered a cereal.

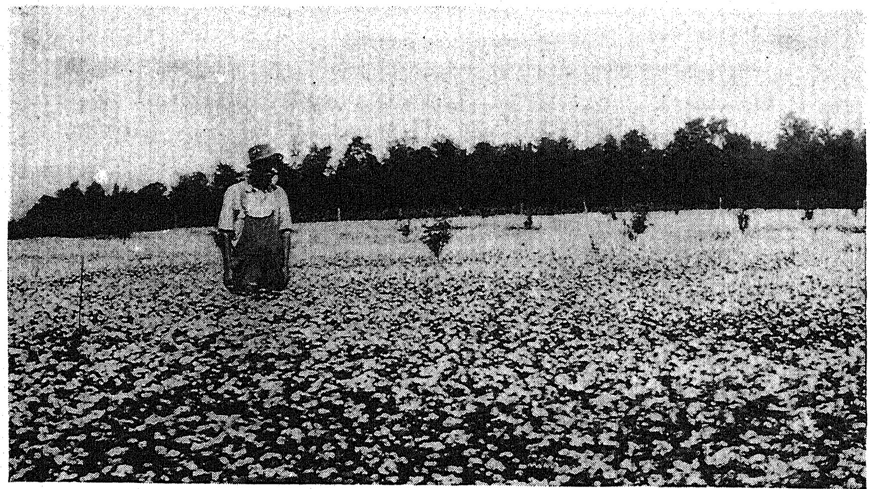

FIG. 61. A field of buckwheat. (*U.S. Dept. Agr. Bur. Plant Indus., Soils, and Agr. Eng.*)

The plant is an annual and grows erect, usually attaining a height of about 3 feet. In contrast to the root system of most grasses, buckwheat produces a taproot with but few branches, the root development being comparatively meager. There is but one stem produced from each seed, and instead of tillers there are produced strong branches at the nodes. The amount of branching depends largely upon the thickness of planting and is less in thick stands. The leaves are alternate, triangular, 2 to 4 inches long, and slightly longer than broad.

The small flowers of common buckwheat are borne in compact clusters on the end of small branches. There are two kinds of flowers produced, one with long stamens and short styles, and the other with short stamens and long styles. A single plant bears one kind, but the seeds from either sort will produce plants possessing either kind of flowers. This is due to cross fertilization; true-breeding, short-styled and long-styled lines may be developed by selfing. The two forms are produced in approximately equal numbers and the existence of two flower forms is thought to be of aid in cross-pollination.

Composition. The buckwheat grain contains somewhat less protein than wheat, rye, and oats and approximately the same percentage as corn. The digestible carbohydrate content is about three-fourths that of wheat, rye, and corn and about equal to that of oats. It has more fat than wheat and rye and about one-half as much as oats and corn. The high percentage of protein and fat in the middlings, which contain the germ, is distinctive.

Uses. The flour made from buckwheat is widely used in the United States for making griddle cakes. The middlings resulting from the manufacture of flour are highly prized for feeding cattle. The grain may also be used for stock feed, especially for feeding poultry.

The crop is used as a means of soil improvement, as a cover crop, and as a honey plant. It seems that buckwheat can use relatively unavailable mineral nutrients in the soil to better advantage than the small grains, and the crop leaves the soil in a good mechanical condition.

Adaptation. The buckwheat plant is best adapted to the northeastern part of the United States, and its culture follows the mountains southward into Virginia and North Carolina. The crop does best in a cool moist climate, being very susceptible to cold. However, owing to its growing season of 10 to 12 weeks, it can be grown in short-season localities. At blooming time high temperature and dry weather are especially harmful, as under such conditions the flowers frequently set seed sparsely. In order to overcome these adverse conditions the crop is usually sown so that it will mature in the fall.

Buckwheat will do well on most well-drained soils. It cannot compete with the ordinary grain crops on productive soils, but on poor soils it is frequently more profitable than the true cereals. Lime is not necessary; in fact, the crop seems to prefer acid soils.

Culture

Methods, Rates, and Dates of Seeding. Buckwheat may be sown by drilling or broadcasting but the former is generally preferable. The rate of seeding varies from 3 to 4 pecks per acre.

Buckwheat is usually sown about 10 to 12 weeks before the first killing frost in the fall. This practice will allow the crop to mature seed under the cool, moist conditions that generally prevail at this time of the year in the chief buckwheat-growing sections. In New York and Pennsylvania the crop is usually seeded during the last week in June, but the date of seeding may extend from June 15 to July 15. Harvesting in these states takes place about the middle of September or shortly after.

Harvesting. Where the topography of the land will permit, the buckwheat crop may be harvested with the ordinary grain binder. However,

since the crop is commonly planted on steep, rough lands, it is most frequently harvested with the grain cradle. The plants are tied in bundles and shocked in the field. The shocks are tied at the top and then left in the field until the crop is ready for storing or threshing, procedures that usually require about 10 days. The crop is usually harvested when the first formed seeds are mature.

RICE (Oryza sativa)

Origin and History. Rice, which is one of the oldest cultivated plants, was grown in China at least 4,000 years ago. It grows in the southern part of China and is evidently native to that country. It was introduced into India from China and was then introduced into western Asia, Egypt, and southern Europe. It was introduced into South Carolina in 1694 and was grown in the Governor's garden in Charleston in that year.

In 1839 about 90 per cent of the rice of the United States was grown on the tidal lands of South Carolina, North Carolina, and Georgia. In that year South Carolina produced 70 per cent of the crop and Louisiana less than 4 per cent. By 1849 the production had greatly increased, especially in Mississippi, Alabama, and Florida, but South Carolina, North Carolina, and Georgia still led in production. In 1859 South Carolina produced more than 60 per cent of the rice crop, and South Carolina, North Carolina, and Georgia together produced 90 per cent of the production.

The Civil War had a profound effect on rice cultivation in the South Atlantic states in that property was destroyed, money and labor became scarce, and the plantations could not be extensively cultivated on account of the lack of funds to finance the production under changed labor conditions. As a result, rice culture became less profitable. However, rice production increased along the Mississippi River in Louisiana after the Civil War partly because less labor was required for its production than for the production of sugar cane. Rice became important in Louisiana about 1887 when it was definitely determined that it could be profitably grown in the prairies of southwestern Louisiana. Since the prairies are divided and broken here and there by sluggish streams, it is easy to secure irrigation water. In 1887 Louisiana became the largest rice-producing state and still leads. As a result of the culture of rice in Louisiana, the production of the crop was developed in southeastern Texas and eastern Arkansas.

In 1912 the first commercial crop of rice was produced in California, mostly in the vicinity of Biggs, in Butte County. In 1922 California ranked fourth in acreage and second in production of rice.

Production. Rice is grown in all tropical countries, but the bulk of the crop is grown in the eastern and southeastern parts of Asia.

The world production of rice during the 10-year period 1931–1940,[7] averaged 7,231,500,000 bushels. China produced 2,484,478,500 bushels during that period; India, 1,950,242,000 bushels; and Japan, 573,877,500. During that same period, 45,712,000 bushels were produced in the United States, but this amount was only about two-thirds of 1 per cent of the world's production.

During the 12-year period 1933–1944, Louisiana produced an average of 20,041,000 bushels of rice; Texas, 12,994,000 bushels; California, 9,823,000 bushels; and Arkansas, 9,753,000 bushels. These four states produced the entire crop in the United States. The acreage of rice in 1939 is shown in Fig. 74.

Description. Rice does not differ greatly in growth from the other cereals. It is closely related to the wild rices (*Zizania*), which grow wild in the regions of eastern America and eastern Asia. Rice is an annual. The root system is fibrous and shallow, the culms average 4 to 5 feet in height, and, like other cereals, rice tillers abundantly under favorable conditions. The flowers are produced in panicles that are somewhat more compact than those of oats, and the one-flowered spikelets are borne on short pedicels. The outer glumes are short scales; the flowering glume, which is sometimes awned, and the palea make up the hull or husk, which envelops the kernel and remains attached to the grain in threshing. The hull varies in color from light to dark brown. Rice which is enclosed in the hull is called "paddy," and that from which the hull has been removed is known as "cleaned" rice. The kernels of the latter are slightly furrowed, hard, and white in color.

Adaptation. Some of the factors affecting the production of lowland rice are irrigation water, precipitation, temperature, and soil, and the most important one is irrigation water. The production of rice is dependent upon an abundant supply of fresh water, as a depth of practically 6 inches of water must be maintained for a period of not less than 75 days. The rice area is also limited by rainfall and temperature, as the crop requires a relatively high humidity and an average temperature of 70°F. during the 4- to 6-month growing season. The precipitation should be well distributed and should be between 50 and 60 inches within the area of production and upon the watersheds of the streams furnishing water for irrigation.

A heavy soil is more desirable than a lighter type, and a subsoil impervious to water must be underneath. The land used for lowland rice production must be in level tracts.

Uses. Rice is used mainly for human consumption and is one of the most important starchy foods of the world, especially in the Orient.

Types and Varieties. There are two general types of rice, the *lowland* and the *upland.* The former is grown on rather low, level land which can be irrigated, and the latter is grown without irrigation just as oats and wheat are grown. Practically all the rice produced in the United States is of the lowland type.

Rice may also be classified as *long grain, short grain,* and *medium grain,* depending on the length of the grains. The seeds of the long-grain rice are long and narrow and average in length 2½ seeds and in width 8 seeds to the inch. The short-grain seeds average 4 seeds in length and 7 seeds in width to the inch. The medium-grain seeds average 3½ seeds in length and 7⅕ seeds in width to an inch. The leading variety of the long-grain type is Rexora; of the short-grain type, Colusa; and of the medium-grain type, Zenith.

Seeding. In the preparation of the land for rice, the field is plowed either in the spring or in the fall and prepared much as for the other cereals. The seeds may be sown broadcast or drilled with a grain drill, the latter method being preferable. A rate of 1 to 2 bushels of seed is used per acre, and the crop is seeded from the middle of April to the last of May. Graded seeds, which have the hulls attached, should be used, and the depth of planting should not exceed 2 inches, since poor seeds and too deep planting are likely to result in poor stands.

Jones,[8] reporting on results of experiments in Louisiana, makes the following statement:

> The usual system of rice and native pasture gives an average yield of about 45 bushels of rice per acre. Fertilizers increase that figure 5 bushels; 4 years of improved pasture between rice crops raises the yield about 12 bushels more, and fertilization, in addition to improved pasture, lifts the yield about 27 bushels. Besides, on such pastures, organic residues are returned to the soil and cause the rice to respond better to fertilizers.

Application of Water. The water should be first applied when the plants have reached a height of from 6 to 8 inches. At this time the subfields are submerged to a depth of 1 to 2 inches and the depth of water is slowly increased until the maximum depth of 5 inches is obtained, when the plants should be at least 2 feet in height. Throughout the growing season the maximum depth of water is maintained by supplying fresh water to restore that lost by seepage, evaporation, and transpiration. When the crop begins to ripen, the water is drawn off to allow the ground to dry out sufficiently for harvesting.

Harvesting. Rice should be cut somewhat before maturity; the proper stage is indicated by the position of the heads, which are well turned down. At this time the kernels in the lower part of the heads have not entirely hardened.

The ordinary grain binder is used in harvesting the crop, and the bundles are shocked and cured in the field like the other cereals; but this method is being replaced by the combine-drier method.

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Topics for Discussion

1. Why do millets find their most important use in sections where grass and clover hays yield well?

2. Do vetches rank high as forage crops?

3. Experiments show that sunflower silage is palatable and that its yield is usually higher than that of corn. Under what conditions should it be substituted for corn?

4. Why is rape not used more extensively in the United States as a forage plant?

5. Why is the production of buckwheat confined largely to the poorer soils and higher elevations of the country?

6. Has buckwheat any particular value for any agricultural purpose other than the production of human food?

7. Show where the production of rice is found in the United States and explain why it is confined to these areas.

8. In view of the enormous amount of human food that rice will produce to the acre, why does this crop not increase rapidly in the United States?

SECTION V

ROOT CROPS

CHAPTER XXXII

SWEET POTATOES, CARROTS, MANGELS, AND TURNIPS

A root crop is one grown for its enlarged roots. In this group are found such plants as sweet potatoes, turnips, rutabagas, and various forms of the beet.

Sweet potatoes, in general, are used as human food, but the other root crops discussed in this chapter are mainly used as root-forage crops.

In the United States root-forage production is chiefly confined to those states in which the climate is unfavorable to the production of corn. The largest acreages are found in the North Atlantic states, though these crops are also grown extensively in certain localities of New York, Michigan, Wisconsin, Minnesota, North and South Dakota, and Nevada. They may be grown in practically all sections where climatic requirements are favorable for the production of corn, but, where the large silage varieties of corn mature well, these afford a cheaper source of succulent winter feed. However, where insufficient animals are kept to justify the erection of a silo, root crops are often grown to supply succulent winter forage, and for this reason small acreages may be found in practically every state of the union where there is sufficient moisture to produce economical yields of corn.

SWEET POTATOES (Ipomoea batatas)

The sweet potato is adapted to regions having a growing period of at least 4 months with warm days and nights, plenty of sunshine, and moderate rainfall. The largest yields are secured when rainfall is abundant in the early part of the growing season and less plentiful during the latter part.

Well-drained soils are necessary for highest yields. The crop thrives best on sandy loam soils but can be grown on a wide range of soils.

Production in the United States. Approximately 90 per cent of the sweet potato crop is grown in the Southern states. The sweet potato acreage is shown in Fig. 62. In the portion of the area that corresponds

approximately to the Cotton Belt, the sweet potato crop is grown on a commercial scale, while north of that section, with the exception of New Jersey, Delaware, and limited areas in Maryland, the crop is grown chiefly for home use.

In the United States as a whole, the average annual production for the 10-year period 1933–1942,[1] was 67,182,000 bushels, with an average acre yield of 84.3 bushels per acre.

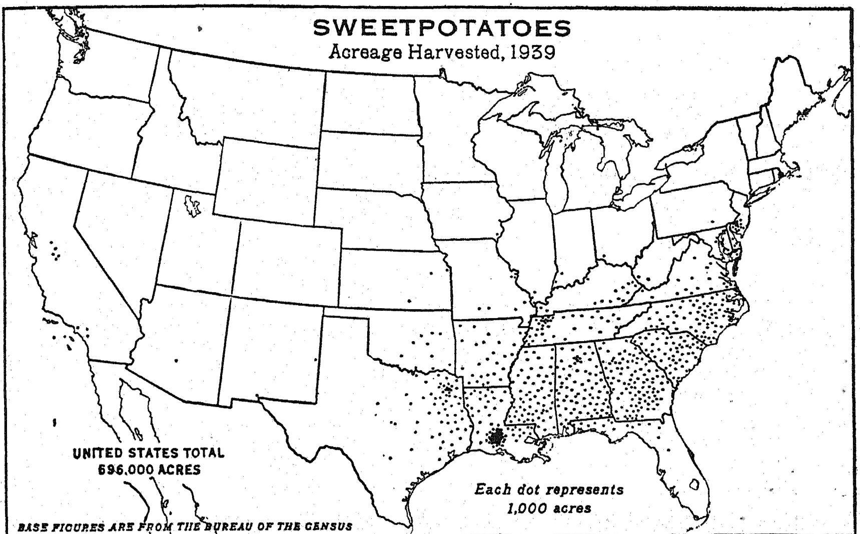

FIG. 62. More than ninety per cent of the acreage or sweet potatoes is in the Southern states, where they are one of the principal food crops. Sweet potatoes thrive best in a climate that has a growing period of at least four months, a moderate rainfall during this period, warm nights, and plenty of sunshine. An ideal soil for sweet potatoes is a light well-drained sandy loam with a clay subsoil. The moist-fleshed sweet potatoes, especially the popular varieties such as the Nancy Hall and the Puerto Rico, are sometimes called "yams." (*U.S. Dept. Agr. Bur. Agr. Econ.*)

During the same period (1933–1942[1]) North Carolina produced 8,362,000 bushels; Georgia, 8,044,000 bushels; Louisiana, 7,034,000 bushels; Mississippi, 6,524,000 bushels; and Alabama, 6,447,000 bushels. Thus, these five states produced 54 per cent of the entire crop during that period.

Historical. Little is known of the early history of the sweet potato, but it is regarded as a native of South America. Columbus found the crop being grown by the Indians in Cuba, and by later Spanish expeditions it was also found growing in Mexico and South America. Sweet potatoes were probably cultivated in Virginia as early as 1610.

Varieties. According to Thompson[2] there are at least two hundred names given to the varieties of sweet potatoes grown in the United States,

but not over forty true varieties exist. Not over ten varieties are of commercial importance and five of these constitute the bulk of the commercial crop.

The Yellow Jersey, Big Stem Jersey, Nancy Hall, and Puerto Rico are the most important commercial varieties and constitute probably 90 per cent of the sweet potatoes grown. The main varieties that are dry and mealy are the Jersey group, and in general are preferred on the Northern markets. The Southern markets usually prefer the moist-fleshed varieties such as the Nancy Hall and Puerto Rico. When the crop is grown for stock feed, such varieties as the Yellow Strassburg, Red Bermuda, and White Belmont are important.

Description. The sweet potato (*Ipomoea batatas*) belongs to the morning-glory family, *Convolvulaceae.* It is a perennial but under cultivation is treated as an annual. The plant is viney, although the varieties are sometimes classed as viney and vineless. The latter term refers to varieties having short, upright vines. The stems are prostrate and frequently during the latter part of the season become rooted at the nodes. The triangular leaf varies much in shape, and the differences are used to some extent in classification.

Uses and Composition. The chief use of the sweet potato is for human food. Sweet potatoes are also used to some extent for feeding livestock. The crop may be utilized for making starch, sirup, and alcohol. The roots contain about 16 per cent starch and 4 per cent sugar, or a total of 20 per cent of alcohol-producing material. A bushel of sweet potatoes should make approximately 1 gallon of industrial alcohol. The vines, when properly cured, make a medium grade of hay.

The edible portion of the sweet potato, according to Langworthy,[3] contains 69 per cent water; 1.8 per cent protein; 0.7 per cent fat; 26.1 per cent sugar, starch, etc.; 1.3 per cent crude fiber; and 1.1 per cent ash.

Culture

"Seeds." The selection of good "seeds" or roots for propagation purposes is important. The best place for selection is in the field, as here the vine growth, yield per hill, and the size and shape of the potatoes can be studied. It is very desirable that potatoes be selected from productive hills and that they be free from disease and well shaped.

Propagation of Plants. Sweet potatoes are grown either from vine cuttings or from slips or shoots produced from roots. When the buds or eyes of the potatoes are placed in beds under the proper conditions of heat and moisture the slips or shoots develop. It usually requires 6 to

8 bushels of seed potatoes to produce sufficient shoots to set an acre from the first pulling. In case two or three crops of slips are to be utilized, then a sufficient quantity will be 3 to 4 bushels of potatoes.

The vine cuttings are secured by cutting sections of vines from plants produced by slips. Vine cuttings are often thought to be preferable to slips or shoots. Vine cuttings are particularly desirable for the production of seed potatoes, as the cuttings are usually free from seed-borne diseases.

Bedding. The potatoes that are to be used to produce slips are usually bedded about 6 weeks before the slips are to be needed. The roots are placed, with the ends pointing in the same direction, in especially made beds, and the development of the slips is stimulated by furnishing the proper amount of heat and moisture.

There are several kinds of beds used, but a common one is the manure-heated bed. A protected place is selected, and an excavation made in the ground to a depth of from 12 to 18 inches. Fresh horse manure is placed in the bottom and thoroughly trampled until the depth is 8 to 12 inches. The manure is then covered with 3 to 4 inches of sandy soil and the bed covered and allowed to heat. After the maximum temperature has been reached and cooled down to 80 to 85°F., a process that usually requires about 4 days, the potatoes are placed in the bed and covered to a depth of 1 or 2 inches with sand. After planting the bed should be kept well watered but not saturated.

Pulling the Slips. The slips should be pulled in such a way as not to disturb the potatoes in the bed. The best method to accomplish this result is to hold one hand on the ground above the potato and pull the slips with the other hand. The placing of small mesh wire over the potatoes before covering will aid in keeping them in place while the slips are being pulled. It is advisable to dip the roots of the slips as pulled into a thin paste made of clay and cow manure. This process is called "puddling." They may then be packed in an upright condition and taken to the field for planting. To stimulate new growth and to settle the soil the bed should be watered after the slips are pulled. If it is desirable to promote vine growth in order to secure vine cuttings from the plant bed, watering may be done with a solution of nitrate of soda (1 ounce of nitrate of soda to 1 gallon of water).

Ridge and Level Planting. The sweet potato crop is usually planted on ridges. The ridges are made with the plow and just before planting are commonly leveled on top. In the cultivation of the crop, the ridge is maintained. However, the crop is sometimes planted level, and it is probable that this method will give about as good results as ridge planting except where the land is not well drained.

Planting the Slips. The slips should not be set in the field until the danger of frost is over. However, they should not be set so late that they will not have sufficient time to fully develop before the fall frosts. It usually requires about 3 to 4 months for the potatoes to reach full development.

A rainy period is preferable for setting the slips, but good results may be secured from setting in dry times by watering the slips when they are set out.

Hand planting is generally followed when the crop is grown on a small scale, and in such cases one person may distribute the slips while another sets them. The holes are usually made for the slips with a sharpened stick or garden dibble. An experienced man can set 1 acre of slips each day, if the slips are distributed by someone else.

Where the crop is grown on an extensive scale, transplanting machines are used. As a rule 4 or 5 acres can be planted with a machine in a day.

Rate of Planting. The rate of planting will vary with the variety and the productivity of the soil. The Southern Queen and Puerto Rico varieties, which produce a large vine growth, should be allowed more room than a variety like the Yellow Jersey, which makes a small vine growth. On good sandy-loam soils the rows are frequently 28 to 30 inches apart and the slips 14 to 18 inches apart in the row. On the poorer sandy soils the rows are often 32 to 48 inches apart and the slips 14 to 24 inches apart in the row.

The number of slips required to plant an acre will, of course, depend on the distance of planting. If the rows are 30 inches apart and the plants 14 to 18 inches apart in the row, 10,000 to 12,000 slips will be required to plant an acre.

Cultivation. The sweet potato crop is usually cultivated with the same implements used in cultivating other crops. As a rule, some form of one-horse cultivator is used, and hand hoeing should be given when necessary. When the vines meet between the rows, cultivation usually ceases, but at the last cultivation it may be necessary to lay the vines aside by hand. However, some cultivators are equipped with a vine-lifting attachment.

Thompson[2] states that, although the difference in yields from plants not moved and those which were moved is not great, it seems safe to say that disturbing the vines after they have grown to considerable length is not justified and is likely to reduce the yield.

Harvesting. If the crop is intended for the early market, harvesting begins as soon as the potatoes reach a marketable size. The main crop should be harvested before freezing weather, since the potatoes are in some danger of being injured if the vines are frozen. However, a light

frost may cause no material damage to the roots. It is advisable, in case the vines are frosted, to cut them at once even though the crop is not to be harvested immediately.

Tools for Harvesting. The kind of implement used to harvest the crop will depend largely on the area to be harvested. When the crop is grown for home use, an ordinary spading or hoe fork is generally used for getting the potatoes from the ground. The ordinary turn plow has been modified in many ways for harvesting the sweet potato crop. Usually a rolling coulter is attached; and when this attachment is made, the first furrow is made with the land side next to the row and the next furrow is so made as to turn the potatoes from the ground. Again two rolling coulters may be attached, and, in such case, one furrow completes the operation, the rolling coulters being used to cut the vines. There are also special implements for digging the crop. The potato-digging machines may cause some bruising when used to dig sweet potatoes, but, according to Brown,[4] there are factors that are in favor of the potato digger for handling a large crop of sweet potatoes.

After the sweet potatoes are dug, they should be placed on top of the soil and allowed to dry. As far as practicable care should be exercised in handling to prevent breaking the skin and bruising.

Storage. The essentials of good storage are that the potatoes be (1) free from diseases, (2) matured before digging, (3) carefully handled, (4) well dried or cured after being stored, and (5) kept at a uniform temperature after curing. Throughout the storage period proper ventilation is important.

Thompson[2] states that sweet potatoes are "cured" by maintaining a high temperature, 80 to 95°F., with good ventilation for a period of 10 days to 3 weeks. He further states that most authorities recommend a storage temperature of 50 to 55°F. after the curing period.

CARROTS, MANGELS, AND TURNIPS

Root crops are grown extensively in Canada, where, as in Europe, they offer an important part of the winter feed ration. They work well into rotations with small grains and grass, furnishing once in the rotation course a cultivated crop that aids in combating weeds and certain other crop pests. Though statistical data are lacking, it is a well-known fact that root crops are grown to some extent in practically every country of the temperate zone.

Historical. The most important root forage crops are the carrot (*Daucus carota*), mangel (*Beta vulgaris*), common turnip (*Brassica rapa*), and the rutabaga turnip (*Brassica campestris*).

The *carrot* is known to have been cultivated for more than 2,000 years,

as it was mentioned by Pliny 300 B.C. It has received more attention in France than in any other country. The great French plant breeder, Vilmorin, is said to have succeeded in developing commercial sorts from the wild form. Though probably a native of Europe, it is now found in all parts of the world. It was grown in Virginia as early as 1609 and in Massachusetts 20 years later, so it probably had an important place in the diet of the early colonists.

The *mangel*, also called "mangel-wurzel," "stock beet," and "field beet," is supposed to have originated by selection from chard, a leafy garden vegetable, which was utilized by the Greeks as early as 300 B.C. The mangel is a native of the Mediterranean area and was grown as a root crop in Germany and Italy as early as the sixteenth century. The sugar beet was developed, by selection for sugar content, from the mangel. The crop was introduced into the United States in colonial days.

Tbe *turnip* is a native of temperate Europe. It was disseminated to Asia after the Aryan invasion and was grown in America as early as 1616. Turnips are not grown extensively for forage in the United States but are important in Canada and the United Kingdom. Most of the prominent varieties are of British origin.

Adaptation. Carrots, mangels, and turnips are best adapted to cool climates with an abundance of sunshine throughout the growing season. After becoming well established, mangels withstand considerable drought throughout the summer months without damage and resume growth when late summer and early fall rains come. For best results mangels should have a growing season of at least 150 days. However, they are quite resistant to frost injury and may be grown successfully where the frost-free period is not more than 120 days. Turnips and carrots are somewhat more exacting in their water requirements and are usually permanently injured by a protracted drought. They mature a crop under favorable conditions within 100 days after planting. Since their seed may be planted safely in the spring 30 days before danger of frost is past, it is often possible to produce a crop before the droughty period of midsummer arrives. However, the seed may be planted in midsummer to mature a crop in the cool moist weather of early fall. These crops do best in deep, loamy soil that is well supplied with organic matter and plant food. Clay soils are not desirable, as the soil bakes, poor stands result, and the young plants grow off slowly. Shallow, infertile soils are not suited to the production of any root crops, as the roots from such lands are not only small, but tough and stringy.

Use and Value. The chief use of root crops is to supply succulent forage for winter feeding. They are, therefore, comparable with silage and should be fed in connection with legume hays or with grass hays and

high protein concentrates for best results. Mangels are used chiefly for cattle and sheep but are sometimes utilized as succulent feed for poultry. Turnips are used principally for sheep but are also relished by all other classes of farm livestock.

Carrots are greatly relished by all classes of stock but are used chiefly as horse feed for fancy horses and as an occasional change of diet for high-producing milk cows. Their comparatively low yield prohibits their use as a substitute for other succulent feed in the regular dairy ration.

Hume[5] has reported the average acre yields of the various root crops as grown in South Dakota in 1914 and 1915 to be as follows: rutabagas, 11.9 tons; mangels, 10.0 tons; turnips, 6.9 tons; and carrots, 6.0 tons.

Although such yields as those reported are not uncommon on fertile soils in cool humid climates, the yields of mangels in the corn-producing sections of the United States seldom exceed that of silage varieties of corn on similar soils, and the yields of the other root crops are correspondingly low.

Composition and Feeding Value. The root crops, as compared with silage, have a lower feeding value. However, they are considered more digestible. They are rather laxative in their effect on the digestive tract, and this, with their low nutritive value, makes them a poor feed when fed alone, but when fed with dry forage and grain concentrates they afford a valuable addition to the ration.

A comparison of the digestible nutrients in various root crops and in corn silage is shown in Table 24, which was compiled from data selected from Henry and Morrison.[6]

TABLE 24. DIGESTIBLE NUTRIENTS IN DIFFERENT KINDS OF ROOTS AND IN CORN SILAGE

Crop	Dry matter in 100 lb.	Digestible nutrients in 100 lb.			
		Crude protein	Carbo-hydrates	Fat	Total
Mangels	9.4	0.8	6.4	0.1	7.4
Rutabagas	10.9	1.0	7.7	0.3	9.4
Turnips	9.5	1.0	6.0	0.2	7.4
Carrots	11.7	0.9	8.6	0.2	9.9
Corn silage	26.3	1.1	15.0	0.7	17.7

These figures readily show why corn silage is a more popular succulent feed than roots, where corn matures well and can be readily ensiled.

Varieties and Types. Mangels are of two distinct colors—yellow and red—and of two distinct shapes—long tapering and globe. Golden

Tankard and Mammoth Long Red are typical representative varieties of the long tapering type, and Yellow Globe and Red Globe are good representatives of the globe type.

Most varieties of forage carrots taper from the crown to the taproot, though some kinds are more or less cylindrical and have blunt tips. The color may be white, yellow, orange, or red. Danvers, Giant White Vosges, Danish Champion, and White Belgian are a few of the more popular varieties.

Rutabagas are usually of a yellowish color and somewhat more tapering than turnips. They grow somewhat deeper in the ground. Two popular feeding varieties are Purple Top Yellow and Sweet German.

The two most widely grown varieties of turnips are Purple Top White Globe and White Globe.

CULTURE

Soil and Seedbed Preparation. The most desirable type of soil for root crops is a well-drained rich silt or sandy loam. A clay soil is not desirable, as the baking of such soils after rains often causes a crust to form that not only interferes with the emergence of the young seedlings but may also cause the pinching off of the young plants. The roots are poorly developed in clay soils and are often irregular in shape and difficult to harvest.

Roots require thorough preparation of the soil before seeding. Deep plowing is desirable, and the soil should be well worked to the depth of 6 to 8 inches. The soil should be made fine and mellow by repeated harrowings until in fine tilth, and then smoothed with a planker or roller. Since the seed of root crops are planted shallow, the land must be smooth and fine in order to ensure even depth of planting and good stands.

Time of Planting. The seed of root crops germinate at relatively low temperatures, and it is desirable to plant them early, so that the young plants may escape serious competition with weeds, which spring up so abundantly on rich soils after the ground is warm. A favorable time to plant is 10 to 15 days before the average last killing-frost date of the section. Mangels and rutabagas keep growing until the heavy frosts of fall occur, and the largest yields are obtained from early seedings. Carrots and turnips require only about 100 days for full maturity. In sections where the growing season is long, they may be planted early, as already suggested, or they may be planted in midsummer, to mature late in the fall.

Method of Seeding. Root crops are usually planted in rows 24 to 36 inches apart. Larger yields are obtained from closer spacing, but if

horse cultivation is to be practiced, about 30 inches is a safer width at which to plant. The seed may be planted by hand or horse drills. In some sections, the seed is placed in the proper seed boxes of grain drills to sow it the right distance between the rows. Turnips and rutabagas may be sown broadcast with good results, and, in some localities, it is a common practice to sow them in mixtures with alfalfa or summer-seeded grasses, using a pound or less of seed to the acre. The roots are pulled out as they mature, leaving the hay crops to occupy the land. The depth of planting is important, and shallow plantings give best results, provided the seed are covered and in contact with moist soil. The depth of covering the seed of mangels and carrots should never exceed ¾ inch, and turnip and rutabaga seed should be covered just deep enough to hide them from view.

Rate of Planting and Thinning. When the seed are planted in drills 30 inches apart, the following amounts of seed per acre are advisable: mangels, 3 to 5 pounds; carrots, 1 to 2 pounds; turnips and rutabagas, 1 to 1½ pounds. When turnips and rutabagas are sown broadcast, 2 to 2½ pounds of seed per acre are recommended.

As soon as the plants are well up and have made four or five true leaves, they should be thinned to the proper distance in the row. The best procedure in thinning is to cultivate first with an implement that has a tendency to draw the soil away from the rows and then "block" out with a hoe, leaving the plants in bunches at the proper distance apart to be thinned to one plant by hand. Only one vigorous plant should be left at a place. If two or more plants are left together, only small inferior roots will develop. Since two or more plants may come from one mangel seed ball, a second thinning may sometimes be necessary. Mangels should be thinned from 8 to 12 inches apart in the row; stock carrots, 6 to 8 inches; and turnips and rutabagas, 6 to 10 inches. Somewhat greater yields and larger roots are obtained from the wider spacings, but better quality is procured from the closer spacings.

Cultivation. Frequent and thorough cultivation is necessary if satisfactory yields of roots are to be obtained. The first cultivation should be given as soon as the rows can be seen plainly, and cultivations should be repeated at intervals frequent enough to keep the weeds down and the soil loose on top. The roots should not be hilled in cultivation. Better results are obtained if the soil is drawn slightly away from the plants rather than toward them. A walking cultivator with narrow hoes is desirable for the early cultivations, but after the plants have reached a height of 4 to 5 inches any type of corn or potato cultivator may be used. It is usually necessary to go over the field with a hoe once or twice during the season to loosen the soil and kill the weeds between the plants in the

row. Cultivations should continue often enough to keep the weeds down until the crop has matured.

Harvesting. Root crops will stand light frost and may be left in the ground until danger of freezing weather approaches. Harvesting may be done by hand or with the specially designed root pullers that are used in harvesting sugar beets. The roots from two to four rows are usually thrown together in a windrow, from which they are loaded into wagons and hauled to the pit or root cellar. Topping may be done either before or after pulling. Perhaps the quickest method of removing the tops is to chop them off with a sharp hoe before pulling. The roots are then loosened with a coulter or subsoiler and pulled from the ground by hand.

Storage. Where roots are to be grown regularly for winter feeding, root cellars should be constructed near where the roots are to be fed. The chief requirements for such cellars are ample space for the roots to be stored, protection from freezing, and a temperature cool enough to prevent rotting. Where possible, the root cellar should be built in a hillside, so that only small portions of the walls are directly exposed to the weather. An air space should be provided in every outside wall. The cellar may be covered with straw or have leaves thrown over its roof as an additional protection against frost.

When no cellar is available, the roots may be stored in pits. The roots are heaped in cone-shaped piles 4 feet in diameter on a clean bed of straw and covered with a 2- to 4-inch layer of long straw. This is then covered with soil to a depth of 6 inches, leaving a 6-inch opening at the peak for ventilation. The ventilator is stuffed with straw to keep out the cold. Additional layers of straw may be added as the weather gets cooler, but a 4-inch layer of straw and a 6-inch layer of soil are usually sufficient where the temperature does not fall below zero. When the roots are wanted for feeding, the contents of a whole pit are taken into the barn at once and protected by covering with straw or hay until used. The roots are prepared for feeding by slicing them into convenient sizes by hand or with a cutter designed for the purpose.

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Topics for Discussion

1. What are the main considerations in storing and keeping sweet potatoes through the winter?

2. Is there a probability of increasing the production of sweet potatoes for feed and manufacturing purposes?

3. What are the most favorable soil conditions for sweet potato production?

4. Discuss the importance of the crop for your state.

5. Why are root crops used more extensively in Europe than in America?

6. Since root crops do not require expensive storage structures in the South, would they be a logical substitute for silage in that section?

7. Why are mangels the most important forage root crop?

8. Under what conditions should carrots be grown for root forage?

SECTION VI

FIBER CROPS

CHAPTER XXXIII

COTTON, FLAX, AND HEMP

The principal fiber plants of the United States are cotton, flax, and hemp. They are grown for their fiber, which is used in making textiles, ropes, twine, and similar materials. Other fiber crops of less importance are ramie, jute, and sisal.

COTTON (Gossypium spp.)

Cotton is the most important fiber crop of the world. The plants that produce it have been known and highly valued from time immemorial. In India, China, Egypt, and America, cotton was cultivated and its fiber made into fabrics, prior to the advent of the Christian Era. It is the most important cash crop of the United States.[1] The soil and climatic conditions of the Southern states are particularly suited to the production of the crop.

World Production. The cotton acreage of the United States in 1939 is shown in Fig. 63. During the period 1930–1939,[2] 47 per cent of the world's cotton crop was produced in the United States on 39 per cent of the world's cotton acreage. From 1925 to 1930, 57 per cent of the world's cotton crop was produced in the United States on 51 per cent of the world's cotton acreage.

Of the average annual world's production of 28,418,500 bales of cotton, the United States produced 13,246,000 bales; India, 4,286,000; China, 2,792,500 bales; Union of Soviet Socialist Republics, 2,597,000 bales; and Egypt, 1,686,5000 bales.

Production in the United States. During the 10-year period 1933–1942,[2] Texas produced an average of 3,273,000 bales of cotton; Mississippi, 1,609,000 bales; Arkansas, 1,314,000 bales; Alabama, 1,011,000 bales; and Georgia 997,000 bales. These five states produced 66 per cent of the total cotton produced in the United States. During this period, the average yield of lint per acre was 236 pounds.

Cotton ranks second in the value of crops produced in the United

States, its value constituting 12.4 per cent of the total value. It is produced on 7.5 per cent of the acreage devoted to crops.[1]

Trends. The cotton acreage in the United States has been reduced from 44,386,000 acres in 1925 to 17,688,000 acres in 1945. However, during that time the yield per acre has just about doubled. Foreign production of cotton has increased 68 per cent between 1920 and 1945, while the United States production has decreased 32 per cent. The

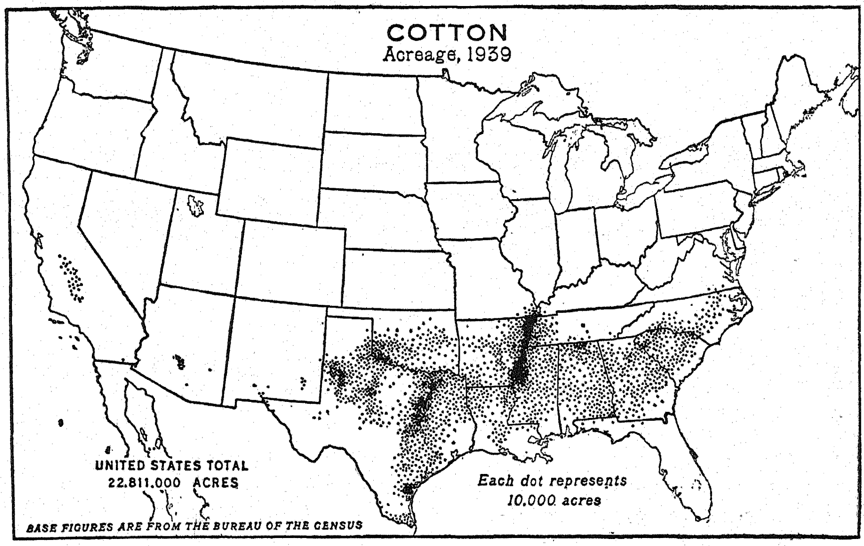

FIG. 63. Acreage of cotton in 1939 was the lowest since 1895. Heavy cuts in acreage under the Agricultural Adjustment Program year after year have brought down the acreage to the present low level. An increase in acreage of cotton in various other countries tended toward a decreased demand for American cotton. Planting of cotton begins in February in the southernmost part of the Cotton Belt and moves northward. Along the northern edge of the belt and in the higher altitudes, planting is usually completed in May. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

export of cotton from the United States diminished perceptibly between the First and Second World Wars from what it was before the First World War.[3] In 1939[2] the United States exported 6,191,000 bales of cotton. The average annual exports in the period from 1940–1944 was 1,372,500 bales. Future exports will depend on how fast the world recovers, foreign production of cotton, and prices.

Another factor affecting the future of cotton is its synthetic competitors, particularly rayon. In the United States the production of rayon has increased from 10,100,000 pounds in 1920 to 724,000,000 pounds in 1944. The world rayon production has increased from 33,100,000 pounds in 1920 to 2,156,500,000 in 1944. Cotton yarn has ranged from 70 cents per pound in 1925 to 66 cents in 1945. During the same period

the price of rayon filament yarn has dropped from $2.05 to 55 cents per pound.

Historical. The early history of cotton is somewhat obscure. It is known that it has been grown in tropical countries of both hemispheres for ages. India appears to have been the center of an important cotton industry as early as 1500 B.C. The cultivation of cotton spread from India to Egypt and thence to Spain and Italy. The Egyptians, Greeks, and Phoenicians had reached an advanced stage in spinning and weaving cotton fiber long before the Christian Era.

England began the manufacture of cotton cloth in the seventeenth century and is now the largest cotton-manufacturing country of the world.

Columbus found cotton growing in the West Indies. It was also found in Mexico and Peru by Cortez and Pizarro, and cotton cloth was found in the ancient tombs of the Incas. Regardless of the fact that the crop was being grown on the American continents at the time of the discovery, cotton did not become of importance in the United States until the latter part of the eighteenth century, when the invention of the cotton gin by Whitney in America and the power loom by Cartwright in England gave an impetus to the cotton industry. Prior to this time, cotton was grown only to a limited extent in Virginia and the Carolinas.

Adaptation. The northern boundary of the Cotton Belt is approximately the line of 200 days' average frost-free season and 77 degrees mean summer temperature; the southern boundary, that of 11 inches autumn rainfall, because wet weather interferes with picking and damages the lint. The western boundary of cotton production, without irrigation, is approximately the line of 23 inches average annual rainfall.

Cotton produces at least one-third of the farm income in five of the Southern states, and comprises about one-eighth of the total value of all crops grown in the United States.

Classification. There are eight commonly recognized species of cotton, as follows:

1. *Gossypium Barbadense*, the long-staple Barbadoes, Sea Island, Egyptian, and Peruvian varieties.
2. *Gossypium herbaceum*, the varieties of India, Siam, China, and Italy.
3. *Gossypium hirsutum*, the American upland varieties.
4. *Gossypium arboreum*, found in Ceylon, Arabia, and South America.
5. *Gossypium Peruvianum*, the native varieties of Peru.
6. *Gossypium purpurascens*, found widely distributed on islands in the Atlantic, Indian, and Pacific oceans.

7. *Gossypium Braziliense*, found in Brazil and other parts of South America. Perennial shrub or small tree.

8. *Gossypium Nanking*, Chinese or Siam cotton.

A number of other species of cotton have been described, but the preceding classes include practically all the cotton of commerce.

There are only two species of cotton grown commercially in the United States—American upland (*G. hirsutum*) and Sea Island (*G. Barbadense*). The American upland varieties have white flowers that turn rose, pink, or red on the second day of blooming. The flowers of Sea Island cotton are yellow with a purple spot at the base of each petal. The flowers are surrounded by deeply fringed bracts that correspond in number to the locks in the bolls. In Sea Island cotton there are usually three bracts, and in the upland varieties four and five are the prevailing numbers. Before they open, the bracts together with the flower buds are called "squares."

Varieties of Upland Cotton. Brown[5] has classified the upland varieties of cotton into seven groups with characteristic variety in each group as follows:

1. *King type*, early, small-boll, short-staple group (King and Oklahoma Triumph—44).
2. *Dixie type*, medium-late, small-boll, short-staple group (Dixie).
3. *Cook type*, round-boll, short-staple group (Cook and Wannamaker Cleveland).
4. *Triumph type*, big-boll, medium staple group (Triumph, Long Star, and Rowden).
5. *Delfos type*, small-boll, long-staple group (Delfos).
6. *Webber type*, big-boll, long-staple group (Deltatype, Webber, and Missdel).
7. *Various types*, mixed or intermediate group.

In this classification, staple length from the shortest to 1 inch in length is considered short staple; $1\frac{1}{32}$ to $1\frac{3}{32}$ inch, medium-length staple; and $1\frac{1}{8}$ inch and longer, long staple. Bolls requiring fewer than 70 to make a pound of seed cotton are considered big bolls; bolls requiring 70 or more, small bolls. Since cotton is very sensitive to such factors as length of growing season, soil type, and moisture supply, many varieties have been developed particularly adapted to more or less local conditions. In sections where storms are prevalent, varieties have been developed that hold their lint well even in severe windstorms. Early varieties have been developed for the northern part of the Cotton Belt and, in recent years, for use under boll-weevil conditions.

Sea Island Cotton. The culture of this species in the United States is restricted to the coast regions of South Carolina, Geogia, Florida, and

a few neighboring islands. The plants grow very tall and have long slender branches. The petals are yellow each with a red spot near the base. The bolls are narrowly ovoid, the fiber long and silky, and the seeds naked and black. The fiber is spun into fine yarns and used largely in the manufacture of laces, cambric, and fine hosiery.

There are no well-defined varieties of Sea Island cotton. The planters make frequent selections that bring out change of type, and these new strains are usually given their breeders' names.

Egyptian Cotton. The culture of this species of cotton in the United States is confined chiefly to Arizona and California. Egyptian cotton is a distinct type, which bears a resemblance to Sea Island. It is used especially in manufacturing goods in which great strength is required, such as automobile tire fabrics and high-quality hosiery. The lint of Egyptian cotton is not white like the upland varieties but is usually dark cream or buff in color. The fiber is 1½ to 1¾ inches in length and very strong.

A characteristic of Egyptian cotton is the tendency of varieties to deteriorate, or "run out," when not subjected to careful breeding and selection. Most varieties that have been introduced into or developed in this country have disappeared after a few years, and other strains have taken their places. At present, selections from Afifi, Yuma, Pima, and SxP-30 are the most important varieties in the United States.

Botanical. Cotton belongs to the *Malvaceae* or Mallow family and the genus *Gossypium*. One of the chief distinguishing features of the Mallow family is that the stamens are united to form a tube around the pistil; and the anthers are one-celled. Okra and a few cultivated flowers, such as hollyhocks, hibiscus, and althea, are also members of this family. From the industrial standpoint, cotton is by far the most important member of the Mallow family.

The genus *Gossypium* includes all species of both wild and cultivated cottons. The plants in this genus have branching stems, petioled and palmately lobed leaves, and showy flowers each with five sepals united into a cuplike calyx and five petals of whitish or yellowish color that often turn pink with age. The seeds are angular and usually woolly but rarely naked. The stigmas are congested and usually number from 3 to 5, equal to the number of locks in the mature boll.

The plant has a taproot with secondary roots that branch laterally from the primary root. The taproot may extend to a depth of several feet under favorable soil conditions, but in heavy clay soils it may be only a few inches long. The secondary roots grow close to the surface of the soil and completely fill the soil area immediately around the plant with a network of lateral roots.

The thick leathery capsule that contains the seeds and lint of the cotton plant is called the "boll." The bolls are ovoid in shape and pointed at the apex. When the bolls mature, they open, exposing the seed cotton.

The Seeds. Within each lock of cotton there are six to ten seeds each covered with lint or long hairs. In upland cotton the seeds are covered with fuzz or short hairs after the lint is removed. This fuzz may be grayish, brownish, or green in color.

FIG. 64. A cotton plant. (*U.S. Dept. Agr.*)

The seeds of Sea Island cotton are black and free from fuzz when the lint has been removed. The proportion of seed in lock cotton (cotton as picked from the bolls) is usually about two-thirds of the total weight. It takes approximately 1,500 pounds of seed cotton to make a bale of 500 pounds of lint. The remainder, 1,000 pounds, contains about 31 pounds of nitrogen, 13 pounds of phosphoric acid, 12 pounds of potash, and 2.5 pounds of lime and is, therefore, very rich in fertilizing constituents. The seed of upland cotton weighs 33 pounds to the bushel and that of Sea Island 44 pounds.

The Lint. Each cotton fiber is a tubular hairlike cell 0.001 to 0.025 inch in diameter. Its length varies from 0.80 to 0.95 inch in the short-

staple upland varieties to 0.90 to 1.5 inches in long-staple upland kinds. The fiber of Sea Island cotton is usually from 1.5 to 2 inches in length. If a cotton fiber is examined under the magnifying glass, it will be found to be somewhat compressed and irregularly twisted. The amount of twist in cotton determines, to a large extent, its spinning quality and hence greatly affects its value. The degree of twist is to a large extent governed by the stage of development of the fiber. The immature fibers have very few twists, whereas mature fibers may have as many as 500 twists to the inch. The strength of cotton fibers varies according to development, fineness, and variety. Williams,[4] of North Carolina, found the average breaking strength of twelve different varieties to be 6.83 grams. The cotton fiber is stronger in proportion to its size than flax or wool, but not so strong as silk and hemp.

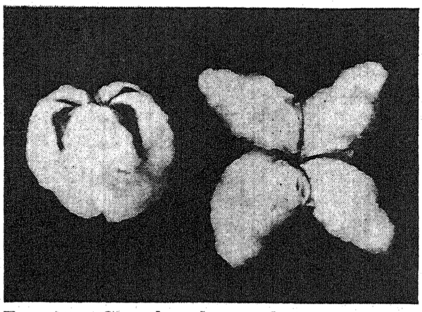

FIG. 65. Closed and open bolls of cotton. (*U.S. Dept. Agr.*)

Classification According to Grade. The Official Cotton Standards of the United States, according to Brown,[5] contain nine grades of white cotton that are named Good Ordinary, Strict Good Ordinary, Low Middling, Strict Low Middling, Middling, Strict Middling, Good Middling, Strict Good Middling and Middling Fair, the last named being the highest. Middling is the basic grade, or the grade on which market quotations are based. Other grade names are used for cotton that is tinged, stained, or discolored in some way.

The grade of cotton is determined by the amount of leaf fragments, trash, and foreign impurities in it; by its color, whether white, tinged, stained, spotted, blue, or gray; and by the preparation or ginning, whether smooth and well ginned or containing neps and gin-cut staple.

Uses. Cotton is grown chiefly for its fiber, which is used in the manufacture of cloth and thread. However, there are a number of by-products that represent a large part of the value of the crop. The seeds are used in the manufacture of feeds for animals, fertilizers, and in the making of oils.

In the manufacture of oil the seeds are first ground; then the hulls are separated, and the oil is extracted from the meats. A ton of cottonseed will usually yield 800 pounds of hulls, 750 pounds of seed cake, and 300 pounds of oil. The remainder of the ton represents loss by evaporation and waste products.

Cottonseed oil has about the same composition as olive oil and is used

for making salads, for cooking, and for lubrication. It is also manufactured into oleomargarine, soaps, and paints. The cottonseed cake is ground into cottonseed meal and used for feed or fertilizer. The meal makes a highly concentrated feed that contains 36 to 41 per cent protein and 5 to 7 per cent fat. It is largely prized as a cattle feed and is used to some extent for horses and sheep. It is toxic to hogs and will cause death if fed in large quantities. It also causes digestive disorders in poultry and young animals when fed in large quantities. High-grade cottonseed contains 7 per cent nitrogen, 3 per cent phosphoric acid, and 2 per cent potash and is used in considerable quantities in the fertilizer industries, particularly when cattle feeds are cheap.

Cottonseed hulls are used as a low-grade roughage for cattle and in the manufacture of paper and fiberboard. They are also used to a limited extent in the manufacture of fertilizers.

Culture

The general cultivation of the cotton crop is much the same as that of corn. For best results the crop must grow rapidly from the start, and cultivation must be such as to encourage quick growth and early maturity.

Preparation of the Seedbed. The time of plowing for cotton is governed to a large extent by the type of soil. On stiff soils and soils covered with much vegetation, plowing in the fall or early winter is desirable. If plowing is done in the fall or early winter, a small quantity of the subsoil may be brought to the surface, as a deep seedbed is desirable. However, when lands are plowed in the spring, it is not desirable to bring the inert subsoil to the top.

Sandy soils that are not covered with vegetation need not be plowed until spring, as they are easily compacted and often have to be plowed a second time if plowed too early. If the land has much vegetation on it, such as corn- or cotton stalks, these should be cut up with a stalk cutter or disked into the soil before plowing. An abundance of organic matter is desirable in case of cotton soils, and cropping systems that bring about this condition are advised. Good drainage is absolutely essential for the economic production of cotton, and the crop should never be planted on wet, waterlogged soils. In order to facilitate drainage in the early part of the growing season, cotton is usually planted on low ridges thrown up by a turn plow. The ridges are commonly thrown up a week or 10 days before planting time so that the soil may become compact. Just before planting time these ridges are run over with a smoothing harrow or similar implement to freshen the topsoil, and then the seeds are planted in the center of the ridges.

Fertilizers and Their Application. Owing to the great variety of soils and the great variation in the productivity of soils, even of the same type, it is impossible to give a fertilizer analysis or to state the amount that will give best results under all conditions. However, for the production of good yields of cotton there must be a liberal quantity of readily available plant nutrients in the soil. For this reason rather heavy applications of commercial fertilizer are generally used throughout the Cotton Belt. A common application is 400 to 600 pounds of a fertilizer carrying 2 to 4 per cent nitrogen, 8 to 10 per cent phosphoric acid, and 2 to 6 per cent potash. In soils that have been made rich in nitrogen by the use of organic matter and legumes, the nitrogen may be entirely omitted, as an overbalance of nitrogen has a tendency to delay the maturity of the crop and to cause too small a production of bolls in proportion to the size of the plant.

In soils rich in potash the amount of potash in the fertilizer may be reduced, but the phosphoric acid is practically always advisable. There are two methods used in applying fertilizer to the cotton crop: (1) distributing in drills and then bedding and planting over these drills, and (2) distributing both the seeds and fertilizers with a machine at one operation. Regardless of the method used, the fertilizer should not come in direct contact with the seeds, as it may reduce germination. When the fertilizer is distributed before planting, it is a good plan, in order to mix the fertilizer with the soil, to run a cultivator through the drill furrow before ridging. Combination planters and fertilizer distributors, which apply fertilizers and plant the seed simultaneously, have been introduced. Data, made available by experiments with machine application of fertilizers to cotton, indicate that, to obtain the most rapid emergence of cotton plants, the best stands, and the largest yields, the fertilizer should be placed in a band about 2 inches to each side of the seed and about 2 inches below the level of the seeds.

Planting. Cotton should not be planted until at least 2 weeks after the last killing-frost date of the section. If planted in a cold soil the seeds are likely to rot rather than germinate. However, the crop should be planted as soon after this time as possible. Early cotton, in most cases, gives higher yields than late cotton, and in the boll-weevil territory the early cotton is not so subject to the ravages of this pest as the late cotton.

Only high-germinating heavy cottonseed should be planted. Investigations show that heavy seeds give higher yields than light or unseparated seeds. One bushel of good cottonseed is sufficient to plant an acre. This amount is more than is required for a good stand if all seeds germinate and grow, but it is considered a good practice to plant an excess quantity of seed and chop with a hoe to the proper stand. The seeds are drilled in

rows $3\frac{1}{2}$ to 4 feet apart, and the plants are left 12 to 30 inches apart in the drill, according to the productivity of the soil. The seeds are covered 1 to 2 inches deep.

Cultivation. The main objects in cultivating cotton are to keep the weeds out and to keep the soil stirred on top until the plants have become large enough to shade the ground completely. Deep cultivation is not advisable. The first cultivation may be given with a section spike-tooth harrow running across the rows as soon as the cotton is up and well estab-

FIG. 66. Four-row cotton planter in operation. Final seedbed preparation and planting is performed in one operation. (*Courtesy of Delta Experiment Station, Stoneville, Mississippi.*)

lished. Subsequent cultivations may be given with any type of cultivator that kills weeds and stirs the soil thoroughly between the rows. After the first cultivation with the cotton cultivator, the crop should be hoed to kill out the weeds between the plants in the drill and to chop out the plants to a proper stand. If the cultivations given thereafter are frequent and thorough, it is not usually necessary to hoe the crop a second time. When the crop is "laid by" it is very important to have the cotton field free of weeds, and this condition should be attained even if more hand work is required.

Harvesting. Until recently, practically all the cotton crop was picked by hand. Picking is a laborious task, the crop being usually limited to the acreage that can be picked. The average cotton picker can gather from 150 to 200 pounds of seed cotton a day, if the crop is good and the open bolls are abundant.

Many mechanical cotton pickers have been invented, but their use

FIG. 67. Four-row flame cultivator being used for weed control in a cotton field. Flame cultivation is proving very effective in replacing slow, costly hand hoeing. (*Courtesy of Delta Experiment Station, Stoneville, Mississippi.*)

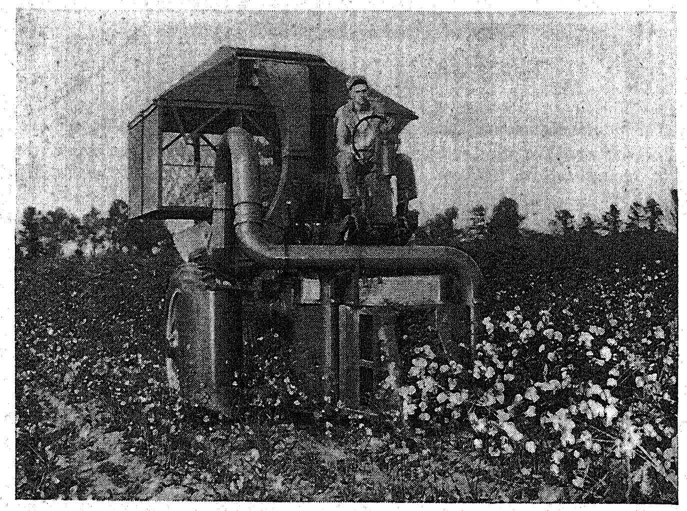

FIG. 68. A mechanical picker harvests the cotton crop on a plantation near Stoneville, Mississippi, October, 1946. (*U.S. Dept. Agr. Off. Inform.*)

has been very limited until the scarcity of labor during the Second World War, and the high cost of labor after the war, brought these machines into more general use on the cotton plantations of the South. Cotton picking extends over a period of several months, the plant pro-

ducing flowers and bolls until frost time. The picking season usually begins in September and continues through December. Thus with the peculiarities of the crop, it hardly seems possible that a machine could do a good job of picking the entire crop at one operation. Since quality and completeness are sacrificed in favor of speed, the mechanical picker may come into its own during periods of high-priced labor. The mechanical picker will pick an average of 400 pounds of seed cotton per hour, which is about forty or fifty times faster than average hand pickers. The use of a preharvest defoliant is of material aid in picking.

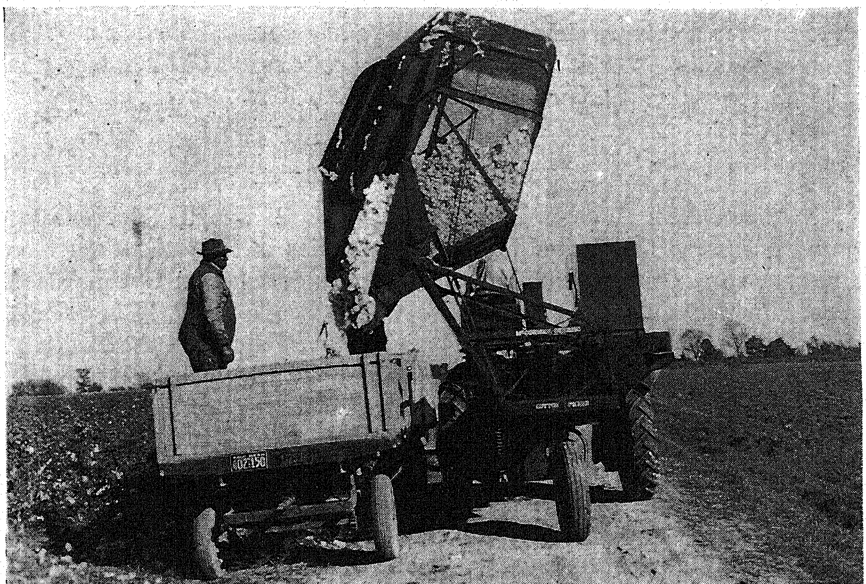

FIG. 69. Unloading mechanical picker into cotton trailer. (*Courtesy of Delta Experiment Station, Stoneville, Mississippi.*)

After the cotton is picked, it is hauled to the gin, where the lint is removed from the seed. The lint is then compressed into bales of 500 pounds each and is marketed in this form.

Making Cotton Cloth. Baled cotton must be thoroughly cleaned of foreign matter, and then it must be opened and fluffed so that the strands may be separated, straightened, brought parallel to each other, and twisted together to make a yarn. In the modern cotton mill all this work is done by machinery. First the bales are broken; then the fiber goes to a scutcher; where it is beaten, shaken, and rolled until all foreign matter is removed and the cotton is placed in layers with the fibers separated. It is then carded, to place the fibers parallel and remove immature fibers and impurities. This process is followed by combing, which removes

short fibers, after which the fleecy lap is condensed through a funnel into a soft untwisted rope or sliver. The slivers are further condensed by a drawing-out process, slightly twisted, and wound on spools. In the spinning process, the cotton is farther drawn out and twisted into a fine yarn of the required strength and firmness. The finished product is wound on a bobbin, or spool, and then goes to the weaving machine, where the warp and weft are interlaced as seen in woven goods.

The woven goods are next bleached by chemical solutions that render the goods a pure white without injury to the fabric. The goods are then dyed and printed to meet the demands of consumers' trade. The higher grade cotton goods are mercerized to give a luster resembling silks. This process consists of treating the goods with caustic soda and other reagents. The process takes its name from its inventor, John Mercer, an English calico printer.

SOME INSECT PESTS

Mexican Boll Weevil. The Mexican boll weevil (*Anthonomus grandis*) entered the United States from Mexico in 1892 and since that time has spread rapidly and caused enormous destruction to the cotton crop. In the adult stage the boll weevil is a beetle about ¼ inch long, varying from ⅛ to ⅓ inch, with a breadth about one-third the length of the body. This measurement includes the snout, which is about one-half as long as the body. The recently emerged weevils are light yellowish in color, but in the course of a few weeks they change to gray or nearly black.

The weevils pass the winter in the adult stage, emerge from hibernation just after the cotton has broken through the ground, and continue until the plants begin to square. The beetles feed only during the day, their food being the foliage, especially the tender terminals. When the squares begin to form, the female beetle deposits eggs in them. In each cavity made by the beetle is deposited one egg, which hatches in about 3 days. The larvae or grubs begin to feed on the embryo flower and in from 7 to 12 days pass into the pupal stage, which lasts from 3 to 5 days. The adult then emerges and in about 5 days begins to produce another generation. It usually requires from 2 to 3 weeks for the weevils to develop from egg to adult. A period of about forty days is required for a complete generation, and usually only four or five generations are produced each season. Males and females are produced in about equal numbers. The males feed upon the squares and bolls without moving until the food begins to deteriorate. The females refrain from depositing in squares visited by other females. This applies throughout most of the season, but late in the fall, when all the fruit has become infested, several

eggs may be placed in a single square or boll. As many as 15 larvae have been found in a boll. The squares are greatly preferred as food and as places for depositing eggs. As long as a large supply of squares is present, the bolls are not damaged to any serious extent. The bolls, therefore, have a fair chance to develop as long as squares are being formed.

The weevil causes the destruction of a great many squares and the most conspicuous evidence of their presence is the flaring and falling of squares in great numbers.

Control. Certain parasites are effective in reducing the attacks of the boll weevil, as they prey upon the immature stages of the insect. Many of the larvae and pupae are killed in the squares that fall to the ground and remain exposed to the sun. The loss from attacks of the boll weevil can be greatly reduced by the destruction of the places of hibernation and of the old cotton plants as soon as the crop is picked. The planting of early-maturing varieties of cotton, liberal fertilizer applications to hasten maturity, and crop rotation are recommended. Arsenical poisons, especially calcium arsenate, have been used with good results in controlling the weevil.

SOME DISEASES

Root Rot. Root rot, according to Neal and Gilbert,[6] is the most important destructive cotton disease in the United States. It is confined largely to the highly calcareous and alkaline soils of the Southwestern states, especially in the heavy black waxy soil areas in Texas. The root rot of cotton and many other plants is caused by a fungus (*Phymatotrichum omnivorum*), which lives in the soil and attacks and destroys the roots. The points of invasion of the root system by the fungus usually are located on the taproot, a few inches below the surface of the ground. The infected areas on the roots are depressed, bronze to dark brown in color, and are separated from the healthy tissue by a reddish-brown border. As growth of the fungus proceeds, the infection spreads and rapidly envelops the greater portion of the root system. On roots infected for some time the bark is so shrunken and soft that it slips easily from the wood. By the time the roots have become seriously injured, absorption of water from the soil is so diminished that the plant cannot replace that lost by transpiration from the leaves, and it wilts.

In addition to cotton, more than six hundred cultivated and wild plant species are known to be susceptible to root rot. Important cultivated plants attacked by the disease include alfalfa, clovers, peas, beans, peanuts, sweet potatoes, turnips, carrots, fruit trees, shade trees, and ornamental trees.

A 2-year, or preferably a 3-year, rotation of grain crops, combined with deep tillage immediately after the grain is harvested, has reduced the disease somewhat. Liberal applications of organic manures have been effective in some irrigated regions. Soil disinfection with formaldehyde or ammonia water may afford protection in small areas.

Cotton Wilt. Cotton wilt or blackroot is caused by the fungus *Fusarium vasinfectum.* The disease often occurs with root knot.

The fungus plugs the water ducts in the stems and thus brings about wilting and death of the affected plants. Since the dead roots of the diseased plants turn black, we have the name "blackroot." When cotton plants wilt and die without apparent reason, wilt is to be suspected. When the stems of freshly wilted plants affected with this disease are cut near the ground, they have a black or brown appearance. Wilt-affected plants are considerably stunted, and frequently the main stem remains shortened, whereas the lower branches may grow normally. The disease usually occurs first in irregular spots over the field. These spots increase in size from year to year, and the diseased plants begin to die early and continue to do so throughout the season. The disease occurs almost entirely on sandy or sandy-loam soils and is spread by the growth of the fungus through the soil or by any agency that will carry the spores from one place to another. The transfer may be effected by plows, cultivators, feet of men, drainage water, and similar means.

Control. Measures that maintain an adequate content of organic matter in the soil and crop rotation are important supplementary factors in decreasing wilt damage. Wilt and rust are greatly reduced through applications of 600 pounds per acre of 6–8–12 or 6–8–6 fertilizer.

Root Knot. Root knot of cotton is caused by minute eelworms or nematodes (*Heterodera radicicola*). The disease attacks a number of other plants in addition to cotton. It causes great loss to the cotton crop, ranking second only to wilt in its noxious effects. The nematodes enter the roots of the plants and cause irregular swellings to appear on the roots, varying from tiny enlargements to knots an inch or more in diameter.

The disease is most serious on sandy soils, being seldom of much importance on the heavy soil types. The badly affected plants are stunted, the leaves and stems may have a yellowish green color, and, in dry weather, the plants often wilt in the middle of the day. The enlargements that occur on the roots may appear on the small as well as on the large roots. The young galls are almost white but later turn brown and decay. Galls cause stunting of the plants, by cutting off the food and water supply.

The disease may be spread in many ways such as by plows, cultivators,

feet of men and animals, use of infected manure, drainage water, and similar agencies (Neal and Gilbert[6]).

Control. Neal and Gilbert[6] state that the most satisfactory method of controlling root knot is by the use of a 2- or 3-year rotation of immune crops, care being taken to kill all susceptible weeds and plants that may start to grow. Some of the crops that are immune or practically so are barley, Brabham and Iron cowpeas, corn, peanuts, rye, wheat, and winter oats.

Anthracnose. Anthracnose, also called "boll rot" or "boll spot," is caused by the fungus *Glomerella gossypii.* The fungus attacks the bolls, seedlings, leaves, and stems of the plants. On the boll the disease first appears as small water-soaked areas that increase in size, covering all or nearly all the boll. The spots become black and later have reddish borders and pink centers. The lint from the affected bolls is usually stained pink and is frequently rotten and worthless. The seedlings when attacked often die before appearing above ground. During cold damp weather the fungus may cause a damping off of the seedlings at the surface of the ground, but usually the entire stem below the surface is dark colored and diseased. The attack on the leaves and stems is chiefly limited to weak or injured parts. The leaves sometimes have a yellowish color and wither and die as if frosted. The seed leaves and leaf scars are especially susceptible to infection.

The disease may be disseminated by wind, rain, insects, animals, contamination in the cotton gin, diseased parts of the cotton plant, and by seed. The last method of dissemination is the most important.

Control. In the control of the disease, Neal and Gilbert[6] recommend the use of disease-free seeds and rotation of crops. The seeds to be used for planting should be field selected from plants free of the disease. However, the organism does not remain alive in the seeds for longer than 3 years. The fungus does not remain alive in the field on dead stalks and bolls for much longer than 12 months. Therefore, leaving cotton off the land for 1 year will control the trouble if disease-free seeds are used. Some varieties of cotton are less susceptible to anthracnose than others.

FLAX (Linum usitatissimum)

Although flax was formerly grown chiefly for its fiber, from which linen was made, at the present time the crop is produced in the United States chiefly for its seed, from which linseed oil is made.

According to Dillman and Goar,[7] flax was a migratory crop all through the nineteenth century, advancing from New York and Pennsylvania to Ohio, Indiana, Illinois, Iowa, Minnesota, the Dakotas, and Montana, as new lands were opened to settlement. It was a crop for the pioneer

farmer, always moving a step ahead of the fatal wilt disease that developed in soils frequently cropped to flax. After varieties had been developed that were resistant to flax wilt, flax settled down as a permanent crop in the North Central states. Production in the Imperial Valley of California increased from 1 ounce of seed in 1927 to 242,000 bushels in 1934.

World Production. The flax crop of the world is produced chiefly in those countries where the temperature is favorable for the production of spring-sown small grains. The largest flax-producing countries of the world are Argentina, Russia, India, and the United States. These countries produce 88 per cent of the world's flax. Fiber flax is produced in all the European countries, Asiatic Russia, and to a very limited extent in India and Japan.

The world production for the 10-year period 1930–1939[2] averaged 142,250,000 bushels of flaxseed. However, the estimated average production during the 3-year period 1941–1943 was 171,700,000 bushels.

Production in the United States. The average production of seed flax in the United States during the 10-year period 1933–1942[2] was 17,180,000 bushels. However, in 1943 the yield was 51,946,000 bushels, but only 23,527,000 bushels in 1944. During the 10-year period 1933–1942, Minnesota produced an average of 8,642,000 bushels; North Dakota, 3,078,000 bushels; California, 1,565,000 bushels; Iowa, 1,153,000 bushels; and South Dakota, 1,109,000 bushels. Minnesota produced 15,456,000 bushels in 1943 and 6,514,000 bushels in 1944. North Dakota produced 15,052,000 bushels in 1943 and 7,661,000 bushels in 1944. The acreage of flax in 1939 is shown in Fig. 74.

In recent years some attempt has been made, by commercial concerns who claim to have a superior method of retting and weaving, to introduce fiber-flax production into the South Atlantic states. According to the report of Robinson and Hutcheson,[3] results of experiments in this area do not indicate that its climate and soils are adapted to the production of good yields of high-quality fiber flax. They suggest that, unless some process is discovered that will make a yield of 2 to 3 tons of low-quality unthreshed straw profitable, fiber flax cannot become an important agricultural crop for the section.

Description of Plant. Flax is an annual plant that grows to a height of 12 to 40 inches. It has a distinct main stem and a short taproot. The slender root branches, however, may extend to a depth of 3 to 4 feet in light soil. The flax flower has five petals and a five-celled boll or capsule, which when filled contains 10 seeds. Normally, flax is self-pollinated, and very little natural crossing occurs. The flowers open at sunrise on clear warm days, and the petals fall before noon. The petals are blue, pale blue, white, or pale pink in different varieties. The seeds

usually are light brown, although in certain varieties they are yellow, mottled, greenish yellow, or nearly black (Dillman[9]).

Uses. Linen is the most important product from the fiber of the flax plant. Lower quality fiber is used in the manufacturing of toweling, matting, and rugs. Straw from seed flax is sometimes utilized in the manufacture of paper pulp, tow, binder twine, bagging, insulating wallboards, and numerous upholstery products.

Dillman[9] reports that more than enough cigarette paper to make the 250 billion cigarettes smoked each year in the United States is made entirely from flax straw in this country. Therefore it is no longer necessary to import cigarette paper, made chiefly from linen rags, from Europe. Besides supplying domestic requirements, American cigarette paper is shipped to nearly every tobacco-consuming country in the world.

The chief product from the seed is linseed oil. The paint and varnish industries consume most of the linseed oil; however, it is also used extensively in the production of enamels, linoleum (meaning "from the oil of flax"), oilcloth, and patent leather, and as waterproofing for raincoats, slickers, and tarpaulins. In some countries it is used as an edible oil and in the manufacture of soap. Linseed cake or linseed meal is the flaxseed with the oil pressed out. It is used as a feed for livestock and is prized for its high protein content and its beneficial effects on the digestive system of livestock.

Types and Varieties. There are several distinct types of seed-flax or linseed group. However, nearly all varieties now grown commercially in the United States belong to the wilt-resistant, short-fiber type. The variety that is widely used is Bison. It is exceptionally resistant to flax wilt (Dillman[9]).

Culture

Securing Good Seed. One of the most important factors in successful flax production is the use of clean, plump, disease-free seed. The variety should be known to be resistant to flax wilt, and the seed should be carefully cleaned and graded to remove dirt, chaff, and shrunken seed, all of which may be carriers of disease.

Planting. Flax requires a firm seedbed. Fall plowing is preferable, as it allows time for the soil to settle. The soil should be packed by rolling, disking, and harrowing, and the surface should be made level before seeding. The seed should be sown about 1 inch deep. Deeper planting reduces yields. The grain drill is the usual implement utilized for seeding flax, though the seed may be sown broadcast and harrowed in.

In Montana and the Dakotas the usual rate of seeding for flax is 2 pecks (28 pounds) an acre, whereas in eastern Minnesota, where the

rainfall is greater, and also under irrigation, it is considered an advantage to seed 3 pecks (42 pounds) per acre (Dillman[9]). Under irrigation and in humid regions, heavier rates of seeding are made, as they have a tendency to keep down weeds. Under dry-farming conditions the usual rate of seeding is 2 pecks to the acre.

When flax is sown for fiber production, it is seeded at the rate of 6 pecks to the acre. Thick seedings keep down weeds and increase fiber yields.

Young flax plants are very resistant to frost injury, and since early seedings are less injured by hot, dry weather than are later ones, it is desirable to sow the seed 15 to 20 days before the last average killing-frost date of the section.

Irrigation. Flax is grown under irrigation only to a limited extent, although experiments indicate that it responds well to irrigation. Since flax is a comparatively shallow-rooted crop, it responds better to light irrigations. When the crop begins to ripen, it is desirable to withhold irrigation in order to hasten maturity; if the soil is kept wet, blooming may continue indefinitely (Dillman[9]).

Harvesting. Seed flax may be cut and bound with a grain binder, after which the bundles are placed in small ventilated shocks until thoroughly dry. It may be threshed directly from the shocks, or it may be stacked after it is thoroughly dry and threshed later. Thorough drying before threshing or stacking is essential to the production of high-quality seed for either oil or planting. Where weather conditions are favorable for full ripening and drying in the field, combines may be utilized for harvesting flaxseed.

The seed should be recleaned before marketing and the screenings kept for feeding at home. Only sound plump seed are desirable for oil making, and dockage of any kind reduces the selling price.

Flaxseed yields from 32 to 44 per cent of oil, based on dry weight. In commercial crushing about 19 pounds, or 2½ gallons, of oil are obtained from a bushel of seed. A part of the oil, 3 to 6 per cent, remains in the cake. Both the quantity and quality of the oil are influenced by the climate, especially by the amount of rainfall and the temperature under which the crop is grown (Dillman[9]).

Fiber flax is usually harvested by pulling. However, specially devised binders are now being used, which cut the plants close to the ground and bind them in bundles. After the bundles are dry, the seed is threshed in such a way as to prevent the breaking of the straw. The straw is then retted to remove the gums and resins from the fiber. The retting may be simple exposure of the straw to the weather until the dew and rains have removed the resins and the fiber is loosened, or more compli-

cated chemical methods of soaking in water under specific regulation of time and temperature may be practiced. When the straw has been properly retted, it is broken and scutched to separate the fiber from the bark and stems, after which it is baled and is ready to be manufactured.

Since the main use of flax in the United States is for seed, very little has been said in reference to its use as fiber. An excellent treatise on this subject has been prepared by Robinson.[10]

HEMP (Canabis sativa)

Hemp is the oldest cultivated fiber plant. It is cultivated for its soft bast fiber, which yields the strongest and most durable fibers of commerce. The name "hemp" is correctly applied to both the plant and its fibers.

World Production. Hemp is cultivated commercially for fiber production in Russia, Italy, Austria, Hungary, Germany, France, Belgium, Turkey, China, Japan, and the United States.

According to Wilsie and others,[11] hemp production declined in the United States until a low of 1,200 acres was reached in 1933. Since 1939, because of the stimulation of an increased demand due to war conditions, production again increased. In 1942 there were about 7,500 acres grown for fiber in Wisconsin, 5,000 in Kentucky, 600 in Minnesota, and 500 in Illinois. Production of hemp in the United States was a war necessity, and in 1943 the states of Iowa, Minnesota, Wisconsin, Illinois, Indiana, and Kentucky were asked to produce 300,000 acres.

Historical. Hemp was probably the earliest plant cultivated for its fiber. Chinese writings indicate that it was used for the manufacture of cloth as early as the twenty-eighth century B.C. There are also indications that it was used in Persia as a drug as early as 1400 B.C. It was probably introduced into Europe by the Scythians in their westward migration and is mentioned as being used by the Gauls as cordage for their vessels in 270 B.C. Nearly all the early botanical writers of Europe mention the use of hemp for cordage, grain, and drug production. It was introduced into America by the Puritans, and its production continued for sometime in Connecticut and Massachusetts, but it was finally superseded by flax for supplying fiber for household industries. It received more attention in the Virginia colony and was carried from there to Pennsylvania, where it enjoyed a period of extensive popularity just prior to the Revolutionary War. According to Dewey,[12] the first crop of hemp in Kentucky was raised by Archibald McNeil near Danville, in 1775.

Botanical. Hemp is an annual plant belonging to the mulberry family, *Moraceae*. It is closely related to the Nettle family, *Urticaceae*,

which includes several Asiatic fiber plants, of which ramie is the most important. Hemp has a rigid stalk, which under favorable conditions may attain a height of 15 feet. The stalk is more or less fluted with well-marked nodes at intervals of 6 to 15 inches. When not crowded, the stalks may attain a thickness of more than 1 inch in diameter, but when crowded for fiber production they are not more than half as thick. The leaves are palmately compounded with five to eleven dark-green lanceolate leaflets and are opposite, except on the shortened branches near the top. When not crowded, the plants have numerous spreading branches, but, when crowded, no branches appear except near the top.

Hemp is dioecious, the staminate flowers and the pistillate flowers being grown on separate plants. The staminate plants are called "flower plants" because the flowers of the pistillate plants are inconspicuous and are seldom seen. The staminate plants die after the pollen sheds, but the pistillate plants remain alive for 1 or 2 months longer, when the seed have ripened. The stalk is hollow, and outside of the hard woody shell is the bark or bast with its long thick-walled cells, which make the bast fiber.

Uses. Hemp is cultivated in warm countries for the production of a narcotic drug, but in cool and humid regions for fiber alone. In early Colonial times, it was used extensively for the production of homespun and other coarse cloth. At the present time, it is used chiefly for the production of twine and ropes. It is used also for bagging, carpet warp, rugs, tarpaulins, sails, upholstery, and for many other textile articles where strength and durability are desired. Owing to its coarseness, it cannot compete with cotton, flax, and wool as a material for clothing and cloths for similar uses.

Jute and sisal are the two most important competing fibers, and the importance of these fibers has been largely responsible for the decreasing acreage of hemp in the United States. Though seldom grown in this country for its seed alone, the seed find a ready market for pigeon and other bird foods.

Adaptation. Hemp grows best in humid climates where the temperatures range between 60 and 80°F. during the growing season. It requires a frost-free period of 120 days for fiber production and at least 150 days for full ripening of its seed. Cool, moist weather during the fall and winter, after harvest, are favorable for retting. Deep clay-loam soils containing considerable organic matter are most favorable for the growth of the crop. On the whole, it may be said that the crop is well adapted for growth on all the better cornlands of the United States.

Seeding. Soil is prepared for seeding hemp by plowing during the winter or in early spring and thorough disking and harrowing before planting. The soil preparation is essentially the same as that for small-

grain seeding. The seed are sown broadcast or with specially devised hemp-seed drills at the rate of approximately 1 bushel to the acre. Even distribution of the seed is very important so that stems will be of uniform size. After seeding, the crop requires no further attention until it is ready for harvest.

When the crop is grown solely for the production of seed, the seed are sometimes sown in cultivated rows 3½ to 4 feet apart and the plants are thinned to 8 to 15 inches apart in the row. After the male plants have shed their pollen, they may be cut out and allowed to fall back to the ground, where they serve to mulch the soil. The seed-bearing plants are left until fully ripe, after which they are cut and shocked until dry enough to thresh.

Harvesting. Most fiber hemp is cut with self-rake reapers made especially for harvesting the crop. These machines leave the stalks in bunches, which are allowed to remain as they fall for 2 or 3 days. They are then either spread for immediate retting in the field or are tied in bundles and set in shocks. In sections where the weather is likely to be dry and hot after harvest, conditions are not favorable for immediate retting, and the hemp is either left in the shocks or stacked to be respread when cool, moist weather comes.

The processes involved in the preparation of hemp for the mills are very similar to those already described for preparing flax fiber. The most important difference is that larger and stronger machines are required for breaking the larger and stronger hemp stalks.

Most of the hemp produced in the United States is dew-retted. This process requires from 6 to 14 weeks. When the retting has extended to the point where the bark and the fiber readily separate from the woody portion of the stalk, the stalks are shocked until thoroughly dry, after which they are taken to the breaker, where the woody part of the stalk is broken out and the fiber separated from the bark. The hemp is then baled for shipment to the mills.

On the fertile prairie soils in Wisconsin, hemp produces about 10 to 12 tons of green stalks, or 2 to 3 tons of dry, retted stalks per acre (Wilsie and others[11]). Dewey[13] states that yields are often estimated at 150 pounds of fiber per acre for each foot in height of stalks, where stands are good.

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Topics for Discussion

1. Why is the United States the most important cotton-producing country of the world?

2. Is it desirable that the people of the United States produce cotton at starvation wages in order to retain its cotton market?

3. A crop of cotton removes very little plant food from the soil as compared with other crops. Why, then, are there such large areas of poor land in the cotton belt?

4. What important effects has the boll weevil had on cotton production in the United States?

5. Why is flax a pioneer crop?

6. Is it likely that flax will ever again be an important crop in the East?

7. Why is a large proportion of our linseed meal shipped to Europe?

8. Why is the acreage of fiber flax in the United States so small as compared with the acreage of seed flax?

9. Since large areas in the United States are well adapted to the production of hemp, why is it not more extensively cultivated?

10. In what respects is hemp fiber superior or inferior to cotton and flax fibers?

11. Why was the hemp plant particularly well suited for fiber production before the age of machinery?

SECTION VII

TUBERS

CHAPTER XXXIV

POTATOES (Solanum tuberosum)

The potato is grown in practically every county in the United States. However, the crop does best in regions of relatively cool, uniform temper-

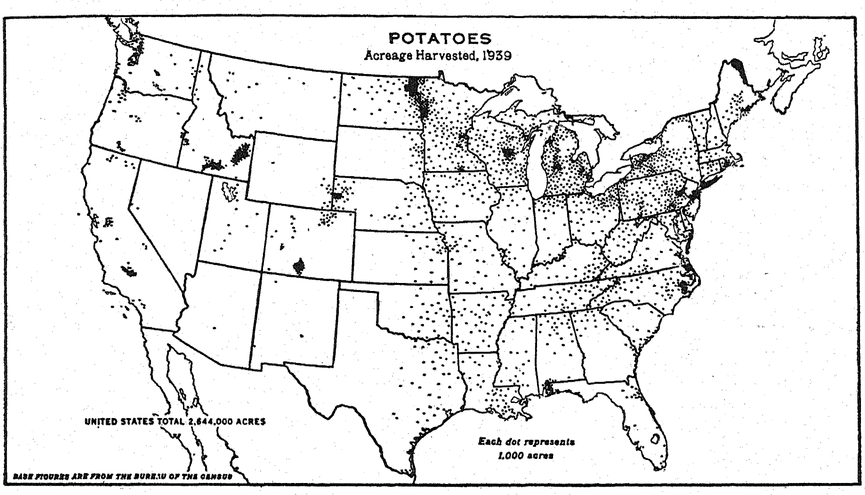

FIG. 70. The acreage of potatoes in the United States extends from the tip of Florida to the top of Maine and completely across the nation from East to West. The early, intermediate, and the late crops are the chief crops produced; they are harvested at various times from January to late October. The early or truck-crop acreage is in the South. The late crop is produced almost exclusively in the North and constitutes over 90 per cent of the total potato production of the United States. In 1939, Minnesota had the largest acreage of potatoes with 222,000 acres; Michigan was second, with 219,000; and New York third, with 189,000 acres. Many of the potato-producing areas are in districts of sandy loam or silt loams—soils having deep mellow subsoil. Although the potato stands second only to wheat as a human food, the per capita consumption has decreased from 196 pounds in 1909 to 140 pounds in 1939. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

ature with moderate rainfall. The soils most desirable are those which are friable, well drained, and comparatively high in humus. As compared with other crops, the potato crop, in 1939, ranked eighth in value in the United States.

World Production. Of the estimated average total production of 7,863,250,000 bushels of potatoes produced in the world during the 10-year period 1930–1939,[1] approximately 25 per cent were produced in the Union of Soviet Socialist Republics, 22 per cent in Germany, 8 per cent in Poland, 7 per cent in France, and 5 per cent in the United States. The average acre yields during the same period were 121, 247, 155, 165, and 112 bushels, respectively. The highest acre yield in the world during that period was in Belgium, where an average of 312 bushels per acre was produced.

Production in the United States. The production of potatoes in the United States is graphically shown in Fig. 70.

During the 10-year period 1934–1943,[1] the five leading states in the production of potatoes were as follows: Maine, 46,102,000 bushels; Idaho, 28,910,000 bushels; New York, 28,595,000 bushels; Michigan, 23,669,000 bushels; and Pennsylvania, 22,318,000 bushels. The average acre yields during the same period were 281, 224, 153, 99, and 120 bushels, respectively. These five states produced 40 per cent of the entire crop during the period enumerated.

Historical. Scientists are agreed that the potato is indigenous to South America and that it probably originated in the central Andean region. However, one group of scientists claims Chile as its original home, whereas another group is inclined to regard Peru as the region from which it came. DeCandolle[2] states that the potato is wild in Chile in a form that is still seen in our cultivated plants, and it is doubtful whether it is native to Peru. Carrier,[3] on the other hand, says: "They were not natives of Ireland as the common name might indicate, but of Peru." The first known reference to the potato in literature is found in Cieca's "Chronicles of Peru," published in 1553, in which volume it is several times mentioned as a common source of food in Peru.

According to Carrier,[3] potatoes were probably brought to England about 1586 by Sir Francis Drake, who obtained them on an expedition to the West Indies. The same author is of the opinion that the first plantings of potatoes in Ireland were made by Thomas Hariot, who was included in the second Raleigh expedition to Roanoke Island and in 1586 was sent to manage Raleigh's estate in Ireland.

The potato did not at first become popular in Europe nor was it used extensively as a food by the early colonists in America. It was brought into prominence by a shortage of other food crops in Ireland and was reintroduced from Ireland to the American colonies under the name "Irish" potato.

The culture of potatoes in the English colonies of America, as a staple crop, seems to have taken place between 1705 and 1749. During that

period a large number of the Irish came to America, and it is likely that they continued the culture of this crop which had become an important food crop in Ireland.

Classification. Potatoes have been classified into twelve groups by Stuart.[4] The distinctions used in classification are shape, color of tubers, color of sprouts, and color of flowers.

In *shape* the tubers may be round, oblong, and long. They may be flattened or round, broad or narrow, spindle-shaped or tapering at one end, or uniform throughout the entire length.

The *color of skin* may be white, creamy white, flesh colored, pink, rose, red and bluish, mottled, and russet brown.

The tubers may also be smooth, russet, or marked with russet dots and varying degrees of russeting. Some varieties are glistening and smooth; others are dull.

The *sprout colors* can best be determined by studying potatoes that have been sprouted in the dark. The base of the sprouts may be either white or colored, as also may the scales or leaflets at the tips of the sprouts.

The ordinary colors are white, creamy white, pink, rose, rose-lilac, magenta, lilac, violet, and deep violet.

The *flower colors* are white, rose, rose-lilac, rose-purple, purple, and violet.

Groups. There are twelve groups of potatoes: Cobbler, Triumph, Early Michigan, Rose, Early Ohio, Hebron, Burbank, Green Mountain, Rural, Peerless, Peachblow, and Up-to-Date.

Varieties. There are four hundred to five hundred, and perhaps a larger number, of varieties of potatoes grown in the United States. Many of the varieties are similar, and frequently different names are applied to the same variety.

The *Cobbler* group, which represents a class of early-maturing potatoes, contains, among other varieties, the Irish Cobbler, Early Eureka, and Potentate.

The *Triumph* group possesses such early varieties as Quick Lunch, Bliss' Triumph, White Triumph, and Warba.

The *Early Michigan* group includes such early white-skinned varieties as Albino, Early Michigan, and Early Puritan.

The *Rose* group is one of the largest, perhaps the largest, and comprises many varieties, some of which are Early Rose, Late Rose, Spaulding No. 4, and Seneca Beauty.

The *Early Ohio* group is extensively grown and on this account is somewhat more important than the Rose group. Some of the varieties are the Early Ohio, Early Six Weeks, and White Ohio.

The *Hebron* group contains varieties that are mostly early maturing.

Some of the varieties are Beauty of Hebron, Early Bovee, and Crown Jewel.

The *Burbank* group is comparatively small but rather important. It includes such varieties as Burbank, Money Maker, California Russet, and Russet Burbank.

The *Green Mountain* group ranks with the Rural group in importance. Among the varieties are Carman No. 1, Empire State, Gold Coin, Green Mountain, Uncle Sam, and White Mountain. These varieties have white sprouts. The Idaho Rural and Charles Downing varieties of this group have colored sprouts.

The *Rural* group contains such varieties as Carman No. 3, Rural New Yorker No. 2, Sir Walter Raleigh, and Late Petoskey.

The *Peerless* group is grown extensively in Colorado, Idaho, and adjoining states. The main varieties are Pearl, People's, and Blue Victor.

The *Peachblow* group is waning in popularity, and the varieties are mostly late maturing. Some of the varieties belonging to this group are Early Peachblow, Jersey Peachblow, McCormick, and White Peachblow.

The *Up-to-Date* group is of European origin. It contains such varieties as Up-to-Date, Factor, and Bull Moose.

The choice of a variety for a given locality should be made upon the basis of such factors as soil type, average growing-season temperature, and market preference. A variety to be popular on most markets today must have white-skinned tubers with few, shallow eyes, and the tubers must be rather short, flat, and of high starch content. Colored-skinned, deep-eyed, elongated tuber varieties are no longer popular except in the case of some early varieties on a few markets (Thompson[5]).

The U.S. Department of Agriculture has carried on an extensive potato-breeding program designed to develop improved varieties. New varieties so developed have been Katahdin, Chippewa, Houma, Earlaine, and Sebago. These varieties are resistant to mild mosaic and bear tubers that are very white, shallow-eyed, and of desirable shape. Sebago is also resistant to late blight. Warba, Sequoia, Calrose, Empire, Mesaba, Nittany, Golden, Pennigan, and Pontiac have also been developed in recent years.

Distribution of Varieties. Potato production is at its best in the northern tier of states, especially the late or main crop. The varieties of the Green Mountain group are best suited to New England, northern New York, Long Island, and New Jersey. The varieties of the Rural group lead in western New York, southern Michigan, Wisconsin, most of Iowa, and portions of Minnesota. In other sections of Michigan, Wisconsin, and Minnesota the varieties of either group may be grown successfully.

In the Western states, such as Colorado, the Intermountain Basin, and the Pacific Coast, the varieties of the Rural, Peerless, and Burbank groups lead.

Structure and Composition. The structure of the potato tuber is shown in Fig. 71. The tuber is composed of four parts, namely, the skin, which makes up about 2.5 per cent of the whole; the cortical layer, which includes 8.5 per cent; and the outer and inner medullary areas, which together make up 89 per cent of the entire tuber. The inner medullary is sometimes called the "core." It is watery and spreads irregularly from the center.

The potato contains about 78.3 per cent water; 2.2 per cent protein; 18.4 per cent carbohydrates, mostly starch; 1 per cent ash; and 0.1 per cent fat. The composition of the different parts is given in Table 25.

TABLE 25. COMPOSITION OF THE DIFFERENT PARTS OF THE POTATO

Part	Starch, per cent	Nitrogenous matter, per cent	Water, per cent
Cortical layer and skin	19.42	1.99	74.79
External medullary area	16.29	2.14	77.44
Internal medullary area	11.70	2.31	82.16

The starch decreases toward the center, and the nitrogenous matter and water increase. However, the digestible protein decreases. The cortical layer, which includes the mineral substances as well as the materials shown in Table 25, is the richest portion of the tuber in food value. About one-fifth of the potato is lost in peeling.

Quality. The quality of potatoes is modified by the character of the flesh when cooked. In quality, potatoes may be mealy, soggy, or waxy.

The mealy potato, which is one with a relatively high percentage of starch, is preferred in the United States. In the cooking process the starch cells burst open, and a light, flaky, uniform mass results.

The soggy potato, which is one with a relatively high percentage of water and a low percentage of starch, is preferred in certain European countries. When cooked, the material remains somewhat heavy and moist instead of light and flaky.

The waxy condition is intermediate between sogginess and mealiness. This quality is often found in new potatoes, on account of the high percentage of protein relative to starch.

Botanical. The potato, *Solanum tuberosum*, is a member of the Nightshade family. It is closely related to tobacco, the tomato, and the eggplant. In the same family are found certain poisonous plants. In

fact, it was once thought that the potato was poisonous, and it was cultivated chiefly as a garden curiosity.

The potato is a perennial, but as a crop it is treated as an annual. The tuber is an enlarged underground stem produced on the end of a stolon and not on the roots proper. Some varieties of potato produce true seeds frequently, whereas others seldom produce them, but the chief mode of propagation is by means of tubers. The tubers bear buds or

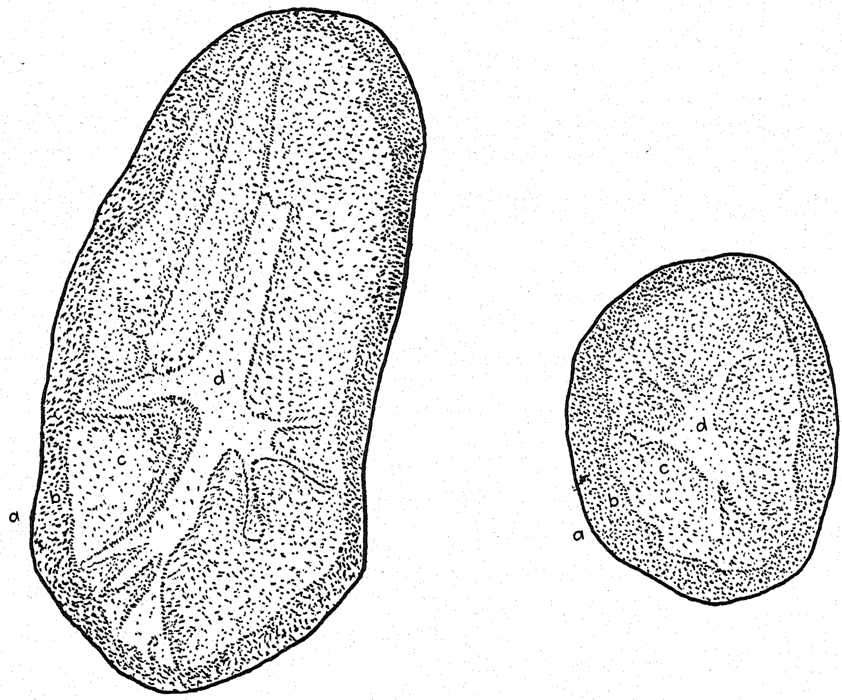

FIG. 71. Transverse and longitudinal sections of the potato. (*a*) Skin, (*b*) cortical layer, (*c*) outer medullary area, and (*d*) inner medullary area.

"eyes" that are arranged in a more or less spiral form. They vary greatly in number and depth, according to the variety. They are much more numerous on the "bud end."

Roots. The roots of potato plants are rather extensive. It has been found that at blossoming time roots meet from plants spaced 3 feet apart each way. Some roots penetrated the soil to the depth of 18 inches, although the main growth was within 8 inches of the surface. Much of the root growth, however, was within 2 or 3 inches of the surface between rows. Roots of some varieties have been observed to a depth of 3 or 4 feet.

Flowers. The flowers of the potato plant are in terminal clusters. Each flower normally has five stamens and a two-celled pistil, and some-

times seeds are formed. The fruit or seed ball is round, has a diameter of about ⅜ inch, and possesses a structure similar to that of the tomato.

The flowers are cross-fertilized, and for this reason when the true seeds are planted the resulting progeny may be different from the immediate parent.

Uses. The potato is used to a great extent as food, especially in some of the European countries. The tuber is prepared in various ways for human consumption. Potatoes are sometimes dried or canned, but this practice is not extensive.

The chief article manufactured from potatoes is starch, which is used for laundry purposes, for the purpose of sizing paper and textiles, and for various other purposes.

Other potato products consist of potato flour, dried or dehydrated potatoes, dextrine, glucose, dextrose or starch sugar, alcohol, and lactic acid (Stuart[6]).

Frequently potatoes are used for feed. About 40 per cent of the crop in Germany is used for this purpose, being fed mainly to swine.

Potato Crops. The potato may be divided into the early or truck crop, the intermediate crop, and the surplus late and other late crops. During the period 1934–1943,[1] an average of 46,686,000 bushels of the *early crop* was produced in 12 Southern states, of which California, North Carolina, and Alabama led in production. The average yield was 97 bushels per acre.

The *intermediate crop* averaged 32,168,000 bushels. Virginia, New Jersey, and Missouri led the 7 states in producing this crop. The average yield of this crop was 113 bushels per acre.

The *surplus late crop* was produced in 17 states, mostly Northern, with an average production of 257,604,000 bushels and an average yield of 137 bushels per acre. Maine, Idaho, and New York led the states in production.

The *other late crop* was grown in 12 states with an average production of 38,633,000 bushels, and an average yield of 105 bushels per acre. Ohio, Indiana, and Iowa led in this production. Considering both groups of late potatoes as a unit, they constitute about 79 per cent of the entire crop.

Culture

Seed Potatoes. It seems to be extremely important to use care in the selection of tubers or "seed potatoes" for planting. There is frequently a marked difference in the yielding ability and adaptability of different varieties. The presence of disease and the source of seed are also worthy of careful consideration.

Degeneracy. Potatoes frequently degenerate, or "run out," and become comparatively unproductive when grown for several years. The trouble is not due to climate, cultural practices, or bacterial or fungous infection, but to virus diseases. The causes of these diseases is not known, but it has been proved that the virus is carried in the plant juices and is spread by plant lice. Plant lice are usually more numerous in the South than in the North, and the diseases are more easily detected and eradicated in the North. Therefore, potatoes "run out" quickly in the South. Le Clerg[7] states that a large portion of the seed stock used in planting the early and main crops in the South is purchased from growers in the North. The use of northern-grown seed is desirable, because in most sections of the South it is not possible to produce seed stock having the same yielding ability and freedom from disease as that grown in the North.

Green Sprouting. Green sprouting of potatoes before planting is recommended by some experiment stations, but the practice is not generally followed. The failure to follow the practice is probably due to the extra trouble involved rather than to the absence of increased yields. The potatoes are brought from the place of storage, placed in the light, and kept at a comparatively high temperature for a period of 2 to 4 weeks before planting. The sprouts produced are short and stout and the tuber becomes somewhat *greened.*

Hardenburg,[8] after studying the results of a 4-year experiment on green sprouting of seed of Rural and Green Mountain varieties, concludes that (1) green sprouting effected an earlier come-up and a more rapid early growth rate, (2) fewer stems per plant resulted from the greening process, (3) greening increased the number of stolons per stem, and (4) greening resulted in an increase in the percentage of U.S. No. 1 yield per acre.

Seed. Thompson[5] states that three factors determine whether seed tubers should be cut or planted whole, namely, (1) cost of labor for cutting, (2) cost of seed, and (3) relative efficiency of cut and whole seed. Generally the comparative cost of seed and labor are such that it is more profitable to cut seed than to plant it whole. Relatively little seed weighing more than 2 ounces, or of hen's-egg size, is ever planted. Most of this is cut. All other factors being equal, whole is better than cut seed, because it is less likely to rot or become diseased after planting and because it will not lose vitality through bleeding and drying.

Whether small or large tubers are the better for seed depends principally on whether the small tubers are from high-yielding healthy stock or only representative of the culls and small tubers from diseased and low-yielding hills.

Stewart[9] reported that uncut tubers between 1 and 2 ounces in weight are at least as good as, and probably better than, pieces of equal weight cut from large tubers of the same plant. In his tests, however, a high-yielding healthy strain of seed was used. Most experiments comparing yields from large and small tubers have resulted in both total and marketable yield in favor of large tubers. Much more seed per acre was planted, however, when the large seed was used.

Hardenburg[10] summarized a review of literature in connection with survey work done in New York State as follows:

1. Large seed tubers seem to give larger yields than small seed tubers.
2. There is no definite proof that whole seed are any more profitable than cut seed.
3. The use of small whole seed is probably profitable especially if separated as culls from a crop produced in another section.
4. Large seed pieces produced larger yields than small seed pieces. It will of course require more seed to plant an acre with large seed pieces than with small ones, and the amount of seed should be taken into account in a discussion of the results.

Stuart and others[11] state, "It does not make any serious difference in the total yield (of potatoes) whether it (seed piece) is whole, halved, or quartered, except possibly in the case of the 3-ounce set, in which the whole tuber proved somewhat superior to a 6-ounce halved set." This statement was based on the results of experiments conducted in Virginia, Maine, Colorado, and Idaho. The total yield per acre from 1-ounce whole potatoes was 279.7 bushels; 2-ounce potatoes, halved, 271.2 bushels; 4-ounce potatoes, quartered, 276.8 bushels; 3-ounce potatoes, halved, 305.7 bushels; 6-ounce potatoes, quartered, 307.0 bushels; 2-ounce whole potatoes, 327.1 bushels; 4-ounce potatoes, halved, 326.0 bushels; 3-ounce whole potatoes, 360.9 bushels; and 6-ounce potatoes, halved, 333.9 bushels.

Conclusion Regarding Type of Seed. Hardenburg[10] in regard to the use of different types of seed, states as follows:

> The foregoing review of the question of large as compared with small seed shows that few tests have actually proved any superior merit of large seed, except as the amount used per acre was increased. The few tests of a more comprehensive nature have indicated that equivalent amounts of smaller seed pieces, down to a minimum weight of 1 ounce, planted closer, may give even more efficient results.

Number of Eyes. Hardenburg[10] has reviewed the results secured in regard to the number of eyes to the seed piece in relation to yield. It seems that, as the eyes to each piece increase in number, the total yield

of potatoes increases, but the yield of marketable tubers decreases. In the work of Zavitz in Canada, 1-ounce seed pieces containing one, two, three, four, and five eyes, respectively, were used. Here also the total yield increased, but the yield of marketable potatoes decreased. The difference in yield of marketable tubers did not vary more than 5 per cent. Apparently "nothing is to be gained by cutting to a certain minimum number in preparing seed for planting."

Immature Seed. It is a common practice to use immature seed in planting the early or truck crop of potatoes. It is thought that such seed are more productive and ripen earlier than mature seed. The northern seed so extensively used in the South is often somewhat immature. In Europe it is also a common practice to use immature seed for planting purposes.

Stuart and others[11] studied the results of experiments from six widely separated states where mature seed was compared with immature seed. In all but one state the yields were in favor of immature seed. The average yield of prime tubers in the six states was 237 bushels from the use of mature seed and 303 bushels from the use of immature seed.

Apical Compared with Basal Seed. The relative value of seed from the apical, or seed, end of the potato and the basal, or stem, end shows but little, if any, consistent differences. However, Stuart and others[12] have found that as the weight of the seed piece increases there is a greater yield from the seed than from the stem-end seed piece.

Ellis[13] noted that yields of No. 1 tubers on muck soils from seed cut from apical and stem ends, respectively, were from Irish Cobbler 362.0 and 340.7 bushels per acre; from Russet Rural 270.9 and 218.7; and from Chippewa 259.4 and 132.0 bushels. Hills from stem ends, especially of Chippewa, emerged more slowly than from apical ends.

Time of Planting. The time of planting is governed primarily by the date of the last killing frost. However, planting may be earlier in light soils than in heavy soils, other things being equal. The crop is usually planted to utilize the cool season of the year. In the South the potatoes are planted early so that the plants will make their growth before the hot midsummer. However, the crop may be planted later, and the main growth made in the fall. In the North the planting is late to utilize the cool fall weather.

If possible, potatoes should be so planted as to bring the period of blossoming and tuber setting during a time when weather conditions are optimum. Hot dry weather at this critical period in the life of the plant seriously interferes with the setting of tubers and consequently with the ultimate crop. Under average conditions and with most main-crop varieties, tubers are formed about 6 weeks after the planting date. In

the leading potato-producing states, the average date of planting varies from May 15 to June 15. Thus July weather is usually very influential on potato yields (Thompson[5]).

The planting date of the early crop of potatoes in the South varies from Jan. 1 to Mar. 15 in Texas, to Mar. 15 to Apr. 30 in West Virginia.

In brief it may be said that the early crop of potatoes is planted as soon as the ground can be worked. The time of planting the late crop varies in different sections of the country. The object is usually to utilize to the greatest extent the cool growing part of the season.

Rate of Planting. The rate of planting will of course vary, among other things, with the size of seed piece and distance of dropping, as shown by Stuart[14] in Table 26.

TABLE 26. QUANTITY OF POTATOES REQUIRED TO PLANT AN ACRE AT DIFFERENT SPACINGS WITH SEED PIECES OF VARIOUS SIZES

Spacing of rows and seed pieces	Bushels of seed required, the average weight of seed pieces used being as given						
	½ oz.	¾ oz.	1 oz.	1¼ oz.	1½ oz.	1¾ oz.	2 oz.
Rows 30 inches apart:							
8-inch spacing.......	13.6	20.4	27.2	34.0	40.8	47.6	54.4
12-inch spacing.......	9.1	13.6	18.2	22.7	27.2	31.8	36.3
16-inch spacing.......	6.8	10.2	13.6	17.0	20.4	23.8	27.2
24-inch spacing.......	4.5	6.8	9.1	11.3	13.6	15.9	18.2
Rows 36 inches apart:							
8-inch spacing.......	11.3	17.0	22.7	28.4	34.0	39.7	45.4
12-inch spacing.......	7.6	11.3	15.1	18.9	22.7	26.5	30.2
16-inch spacing.......	5.7	8.5	11.3	14.2	17.0	19.8	22.7
24-inch spacing.......	3.8	5.7	7.6	9.5	11.3	13.2	15.1
Rows 42 inches apart:							
18-inch spacing.......	4.3	6.5	8.6	10.8	13.0	15.1	17.3
24-inch spacing.......	3.2	4.9	6.5	8.1	9.7	11.3	13.0
30-inch spacing.......	2.6	3.9	5.2	6.5	7.8	9.1	10.4
36-inch spacing.......	2.2	3.2	4.3	5.4	6.5	7.6	8.6
Rows 48 inches apart:							
18-inch spacing.......	3.8	5.7	7.6	9.5	11.3	13.2	15.1
24-inch spacing.......	2.8	4.2	5.7	7.1	8.5	9.9	11.3
30-inch spacing.......	2.3	3.4	4.5	5.7	6.8	7.9	9.1
36-inch spacing.......	1.9	2.8	3.8	4.7	5.7	6.6	7.6

In northern Maine, according to Stuart,[14] many growers make a practice of planting Irish Cobbler seed pieces 32 by 8 or 32 by 10 inches apart.

According to Le Clerg,[7] the spacing of potato plants in the Southern states is usually 12 to 14 inches and the distance between rows may be

30, 32, 36, or 48 inches. In some of the sugar-cane areas of Louisiana, potatoes are frequently interplanted with sugarcane in rows 6 feet apart.

Stuart[15] states that in dry-land potato production in the Far Western states a much wider row spacing is necessary than under irrigation. Under dry-land conditions the interrow spacing usually varies from 40 to 48 inches and the sets in the row from 18 to 30 inches. Under irrigated conditions the distance between rows ranges from 24 to 36 inches, and the sets may be spaced from 9 to 12 inches apart in the rows, depending on the variety and the fertility of the soil.

The general rate of planting in the United States is 12 to 15 bushels per acre. In Europe the usual rate of planting is 30 to 40 bushels. Larger yields are correlated with high rate of planting. However, after a certain limit is reached, the profit may be reduced by an increased rate of planting.

Depth of Planting. Hardenburg[10] has reviewed a number of experiments relative to the proper depth of planting potatoes in order to secure the highest yields. The conclusion to be drawn is that under ordinary conditions the seed pieces should be covered about 4 inches deep. This depth of planting usually gave higher yields than shallower or deeper planting. It seems that the tubers form at about the 4-inch depth; this depth may be secured by ridged planting or by ridged cultivation.

Hardenburg,[10] reviewing the work of Emerson in Nebraska, states that deep-planted potatoes produce more productive seed than those planted shallow. Seed from the crop planted 4 inches deep yielded better than seed from the crop planted 1 inch deep, while a depth of 7 inches was better than a depth of 4 inches.

The results in New York indicate that on the light soils the planting can be comparatively deep, and on the heavier soils it should be shallower.

Method of Planting. The planting of potatoes in drills is more common than planting in hills. Hardenburg[10] states that in Michigan drilled potatoes yielded 12 bushels more to the acre, in the case of the Early Ohio variety, than those planted in check rows. In case of the Rural New Yorker No. 2, the yield was 29 bushels per acre in favor of the drill method. From the drilling method, Zavitz in Canada obtained an increase of 39.8 bushels per acre over planting in check rows. The results of the experiments reviewed by Hardenburg[10] show that irrespective of the rate of planting, drilling is superior to planting in check rows.

In New York the yield from drilled potatoes was 7.9 to 23.8 bushels per acre greater than that from check-row planting. It required about 3 bushels more seed to plant an acre by the former method.

In drilling potatoes farmers use both the one-man and the two-man planters. Where potatoes are produced in large quantities, machine

planting has displaced hand planting. A planter is profitable where 5 acres of potatoes on the average are grown.

Fertilizer. According to Thompson,[5] such fertilizer analyses as 4-12-4, 5-10-5, 5-8-7, and 10-16-14 have become common. On the sandier soils in the older potato regions of the Eastern states, amounts of fertilizer ranging from 1,000 to 3,000 pounds per acre are commonly applied. On the heavier soils farther inland and particularly in such important potato states as Michigan, Wisconsin, and Minnesota, lighter applications, 800 pounds or less, are used.

Chucka and others,[16] studying the effects of fertilizer on Caribou loam soil, found that, during the 12-year period 1930–1941, 2,000 pounds of a 4-8-7 fertilizer produced 381 bushels while only 123 bushels were produced on unfertilized plots. Increasing quantities of fertilizer (from 1,500 to 3,000 pounds) resulted in progressively larger yields.

Fertilizer Placement. Cumings and Houghland[17] conducted an extensive study during the period 1931–1937 to determine the most advantageous placement in which commercial fertilizer may be deposited with respect to the potato seed piece. The study was made in New Jersey, Ohio, Michigan, Maine, Virginia, and New York. They found that fertilizer placed in a band 2 inches to each side of and on the lower level of the seed piece most consistently produced the most rapid emergence of sprouts, the most vigorous plant growth, and the highest yields of primes as well as total yields.

Level Compared with Ridge Cultivation. The most common method of cultivating potatoes is to ridge the rows. The amount of ridging varies. However, results as reported by Hardenburg[10] show that level culture has given somewhat higher yields than ridging. This result was especially true in dry years and on light soils, but did not hold true invariably. Sometimes, especially in wet seasons, medium ridges, about 4 to 5 inches in height, are advisable.

Frequently the crop is cultivated level, and at the last working a slight ridge is made. The reason often given for this practice is that the potatoes are protected from the sun.

Relation of Date of Harvest to Yield. Unless the price and other factors demand, the potato crop should not be dug until the foliage dies in the course of natural maturity. Hardenburg[10] states from work done in Rhode Island that potatoes increased in yield from 30 bushels per acre on Aug. 2, to 353 bushels per acre on Sept. 22. Of this increase, 119 bushels were obtained after Sept. 1, and there was a 50-bushel increase the last 10 days. The crop was planted on May 20. In Minnesota the Early Ohio variety of potatoes increased in yield from 10.9 bushels per acre on July 31 to 226.8 bushels per acre on Aug. 30. The average daily

gain of marketable potatoes throughout the period was 7 bushels, while the yield increased 44.7 bushels per acre during the last week. These data show the great increase in tuber yield during the last stages of growth of the plants.

Methods of Harvesting. There are various methods of digging potatoes, such as by hand, by plowing, and by the use of various types

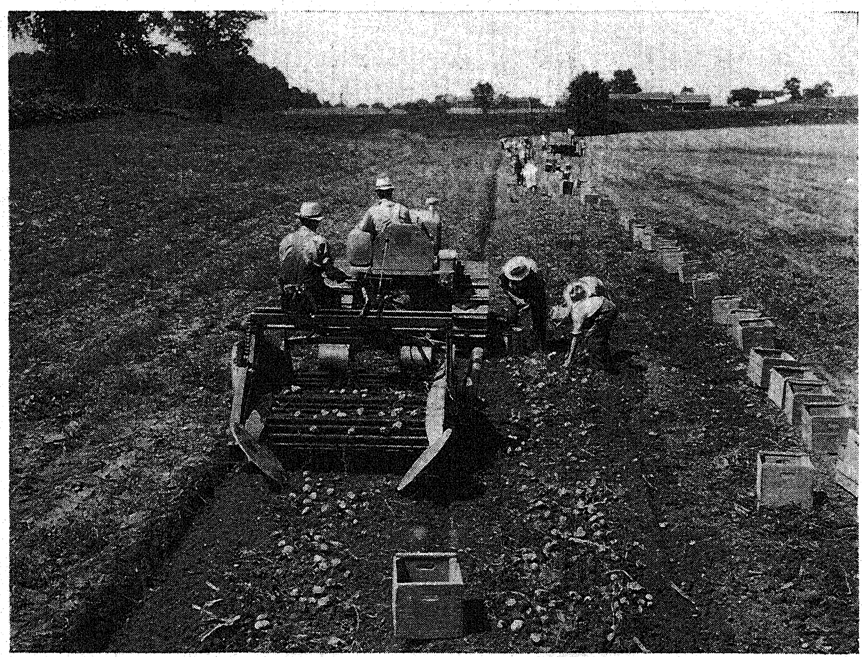

FIG. 72. Modern two-row potato digger. (*Courtesy of American Iron and Steel Institute.*)

of machine diggers. Hardenburg[10] finds that when as many as 5 acres of potatoes are grown on the average annually, it is profitable to use a machine.

Weather plays an important part in determining time of harvest because it is desirable from the standpoint of disease and keeping quality that the tubers go into storage in a clean and dry condition. Potato tubers keep better and bruise and peel less if allowed to remain on the ground after digging for 1 or 2 hours until the skin "sets" (Thompson[5]).

Storage. Potatoes are stored in field pits, in cellars, and in refrigerated storage houses. The successful storage of potatoes depends upon the quality of the product, the temperature in storage, the humidity of the air, the size of the storage pile, and the exclusion of light. The proper temperature of potato storage is from 38 to 40°F.

SOME INSECT PESTS

Colorado Potato Beetle. The Colorado potato beetle (*Leptinotarsa decemlineata*) in the adult stage is ovoid in shape, about ⅜ inch long, and about two-thirds as wide as long; it is yellow in color with the wing colors showing 10 longitudinal black lines. The head has a triangular black spot, and the thorax contains 10 or more spots and other markings. The larvae are soft and Venetian red when first hatched; later they become paler.

The adult beetle enters the ground during October and hibernates there until warm weather in the spring. The beetles then emerge, and the female deposits eggs on the underside of the leaves of the potato plants as soon as they appear. The eggs hatch in about one week and the larvae produced as well as the adult beetles feed on the foliage of the potato. The larvae after 2 or 3 weeks enter the soil and pupate. In 2 or 3 weeks the adults emerge and deposit eggs for the production of the second brood. The adults from the second brood hibernate during the winter, as there are but two generations each year.

Control. In the control of the pest, DDT may be added to the Bordeaux solution used for blights at the rate of 1 pound of 50 per cent wettable dust to 50 gallons of spray material. If copper-lime dust or neutral copper dust is used for blight, the DDT may be added at 3 to 5 per cent strength.

Preliminary work done by several states indicates that DDT is very valuable in controlling many of the potato insect pests.

Flea Beetle. The potato flea beetle (*Epitrix cucumeris*) is a small jet-black insect similar in habits and life history to the tobacco flea beetle. In addition to puncturing holes in the leaves of the plants, it is important in distributing diseases. It is controlled by the same methods as recommended for the Colorado potato beetle.

SOME DISEASES

Common Scab. The common scab of potato is caused by the bacterium *Actinomyces scabies*. The disease is well known from the rough, scabby pitting produced on the tubers. The tubers may be attacked when very young or later in development. The diseased areas, which are first small in size and reddish or brownish in color, may spread, unite, cover the entire tuber, and become darker in color.

The disease is favored by soils less acid than pH 5.6. Wood ashes, lime, fresh stable manure, and other materials that increase the alkalinity of the soil will tend to enhance the scab injury. The parasite is apparently present in many soils and will live there for many years, especially if the soil is neutral or alkaline. The disease may be easily

spread by the use of diseased tubers for seed and by the application of infested manure on the land.

Control. In the control of the disease, tubers free of the disease should be used when practicable, rotation of crops immune to the disease followed, the use of infested manure avoided, and the soil kept slightly acid when the land is infested. In case it is necessary to use diseased tubers for seed, they should be soaked before cutting for 2 hours in a solution of formaldehyde (1 pint of formalin, containing 40 per cent formaldehyde, to 30 gallons of water). Instead of the formaldehyde treatment a solution of corrosive sublimate may be used. This is made by dissolving 2 ounces of corrosive sublimate in hot water and diluting with cold water to 15 gallons. The uncut tubers should be placed in the solution for 1½ hours. The solution is very poisonous when taken internally. It also acts on metal, and for this reason wooden containers should be used in administering this treatment.

Organic mercury compounds have recently been used very successfully in treating potatoes to control scab. A solution is made by adding 1 pound of the compound to 2½ gallons of water. This amount will treat 12 to 15 bushels of potatoes. The potatoes, cut or uncut, should be dropped into the solution and removed at once and allowed to dry. The specific directions of the manufacturer should be followed. The organic mercury compounds are very poisonous, and the potatoes treated and not planted should be placed where they will not be eaten by persons or livestock.

Early Blight. The early blight of potatoes is caused by the fungus *Alternaria solani,* which attacks the leaves of the plants. The infection is evidenced by spots, which are dark brown or black in color and irregularly circular in outline. They usually show a series of concentric rings giving a "targetlike" effect. These spots, which usually appear about the time the tubers begin to form, may spread over large areas of the leaf surface and thus cause the death of the leaves while the stems are still green. The progress of the disease, in contrast to that of late blight, is slow; usually 3 or 4 weeks elapse before all the leaves are dead. Moisture aids the spread of the disease, whereas drought will check it completely.

In the control of the disease, spraying with Bordeaux mixture (5-5-50) each week is recommended. This spraying should begin when the plants are 6 to 8 inches high and should continue throughout the season of growth. Crop rotation is also of benefit since infection takes place from the spores that have overwintered in the soil on the dead vines.

Late Blight. Late blight of potatoes is caused by the fungus *Phytophthora infestans.* It usually appears in the latter part of the growing season and attacks the leaves, stems, and tubers. It is much more preva-

lent in wet seasons. The disease shows on the leaves as dark water-soaked areas, which may appear on any part of the leaf. The spots frequently begin at the tip or edge of the leaf and spread until the whole leaf is affected. In moist weather the spots rapidly enlarge, and on the lower side of recently affected areas usually a fine white mildew appears. The stem may become affected in a like manner, or sometimes the disease first attacks the stem and then the leaves.

The disease may attack the tubers, and those lying near the surface of the ground are the first to become affected. On the affected tubers are produced discolored water-soaked areas, which may be small or in moist soils may sometimes extend over a large part of the surface of the tuber. These affected areas become sunken by digging time or in storage, and the flesh has a rusty-brown color. The flesh is affected to a depth of about ¼ to ½ inch. This condition is known as "dry rot." While in storage the fungus sometimes spreads from affected tubers to healthy ones. The late blight fungus develops best under cool moist conditions. Tubers will rot but little in storage from late blight infection, if kept in a dry place and held at a low temperature (40°F. or below). Other fungi or bacteria may enter the affected areas and produce a soft, disagreeably smelling condition known as "wet rot." The disease lives from year to year on the affected tubers, and spreads to healthy plants from the vines produced by affected tubers.

Control. In the control of the disease, spraying with Bordeaux mixture (5-5-50) each week is recommended. The spraying should begin when the plants are 6 to 8 inches high and should continue throughout the season of growth. Crop rotation and the use of disease-free tubers for planting are good preventive methods.

Virus Diseases. The virus diseases that cause potatoes to degenerate, or "run out," often greatly reduce the yield and affect the plants in different ways. The names of various virus diseases are taken from the appearance that they produce on the plants. Among the diseases are mosaic, leaf roll, spindle tuber, streak, curly dwarf, and giant hill.

The diseases are seed borne, but no seed treatment has yet proved effective. Seed known to be free from the diseases should be used. The diseases may be greatly reduced by roguing the fields of diseased plants, at least three times during the growing season. The first roguing should take place when the plants are 6 inches tall, the second 10 days after the first, and the third about 2 weeks after the second.

Spraying with Bordeaux mixture to which is added three-fourths of a pint of nicotine sulfate to each 50 gallons of the mixture will help to control the spread of the diseases through destroying aphids. These insects carry virus diseases from diseased to healthy plants.

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Topics for Discussion

1. Is it logical to compare yields of potatoes in America and in Europe in order to illustrate the inefficiency of American farmers?

2. Potatoes remove less plant food per bushel from the soil than cereals. Why are potatoes usually fertilized more heavily than grain lands?

3. List all the industries that may have been concerned in the production of a package of potato chips found in your grocery store.

4. How much of the plant food normally applied to the potato crop in your section is returned in the crop removed?

SECTION VIII

SUGAR PLANTS

CHAPTER XXXV

SUGAR BEETS AND SUGAR CANE

Sugar beets and sugar cane are the principal plants cultivated for sugar products. The sugar beet furnishes the bulk of the sugar produced in the United States, but most of the sugar consumed in this country is imported because the local supply is insufficient. In addition to these crops, the saccharine sorghums are used for making sirup.

SUGAR BEET (Beta vulgaris)

The sugar beet is an important root crop of the world, as approximately one-half of the world's sugar comes from this source.

During the 10-year period 1935–1944,[1] the Union of Soviet Socialist Republics led the countries of the world in the production of sugar beets, with an average annual yield of 16,240,600 tons, but the average acre yield was only 6.5 tons. Germany produced 15,602,000 tons. The average acre yield was 12.9 tons. The United States produced 9,567,700 tons with an average acre yield of 12.2 tons and ranked third. These three countries produced about 52 per cent of the world's supply of sugar beets. Approximately two-thirds, or 67,000,000 tons, of the beets in the United States in the period 1933–1942[1] were produced in California, Colorado, Michigan, Nebraska, and Montana.

The acreage of sugar beets in the United States is shown in Fig. 73.

Historical. Although beets have been cultivated for table use and for stock feed for many centuries, their value for sugar production was not recognized until about the middle of the eighteenth century. At that time German chemists found that the beet contained the highest percentage of sugar of many plants analyzed and began investigations in search of methods of extracting the sugar from them. The first beets analyzed contained only about 6 per cent of sugar, but, by the selection of plants for high sugar content, many crops now yield 15 to 20 per cent.

Beet sugar did not appear on the market until 1812 and then in small quantities. The commercial production of sugar beets in the

United States, however, dates from 1869, when the first sugar factory was established in California.

Description. The sugar beet and mangel are closely related, and the plants show a close resemblance.

The sugar beet is a true biennial and does not produce seed until the second year. During the first year the beet root develops to full size and the second year produces a seed stalk that bears large quantities of

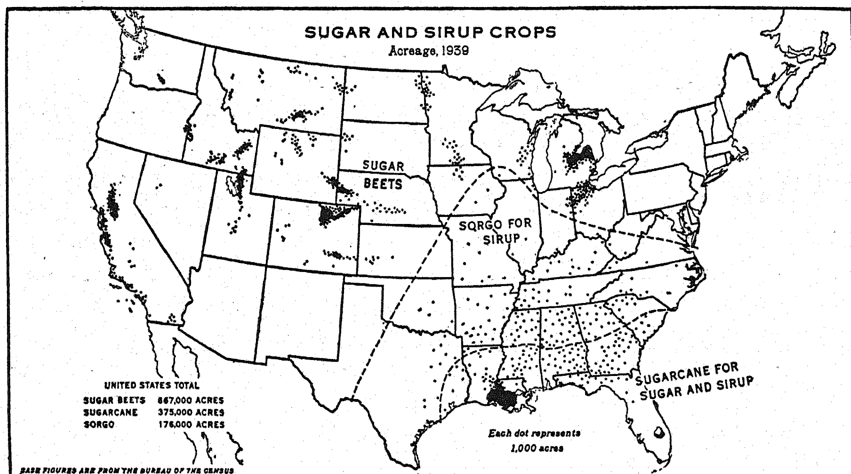

FIG. 73. Sugar is extracted from the juices of the sugar beet and from sugar cane. The product, when pure, is identical in all properties and for all purposes. Successful production of sugar beets requires an adequate supply of moisture, warm days, and fairly cool nights during the growing season. The beet-sugar factories are located chiefly between the isotherms of 67 and 72°F. mean summer temperature (May-September). Production of sugar cane requires a relatively high temperature and considerable sunshine with plenty of soil moisture during the growing season. Sugar cane grown for sugar production in continential United States has been produced chiefly on the fertile alluvial soils of the lower Mississippi Valley in Louisiana and around Lake Okeechobee in Florida. Sorgo is used to make sirup, which is chiefly a farm product, with only small quantities entering the commercial market. Sugar is not made from sorgo. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

seed. The seeds are borne in rough-coated capsules called "seed balls," which contain from three to seven seeds each.

The sugar beet has a large taproot, which gradually tapers into a relatively small root. The percentage of sugar in the beet is lowest at the extreme tip and the extreme top. The maximum amount of sugar is found in the outside layers about one-third of the way down the beet from the crown.

Adaptation. Successful sugar-beet growing has been confined to the temperate region in practically all sugar-beet-producing countries. In warmer areas the roots are not usually sufficiently rich in sugar to make

them profitable in sugar making. In colder areas the seasons are too short for the proper development of the crop.

Practically the entire northern half of the United States is climatically suited for the production of sugar beets, but labor and soil factors confine the crop to rather limited areas. Since sugar beets may be grown successfully on practically all the corn and potato soils of the northern part of the United States, their production will doubtless expand when economic conditions justify increased acreage.

Propagation. According to Carsner and Owen,[2] the production of seed was firmly established in the United States as a result of the need of multiplying American varieties resistant to curly top, a disease that at one time threatened the very existence of the sugar-beet industry in this country. In Europe, the beets are grown one season, dug, stored over winter, and set out in the spring. The method described below is much less laborious. The seed is planted in late summer or early fall, the plants allowed to grow slowly over winter in place, usually without thinning, and the seed harvested the following summer. The method permits mechanized operations that eliminate much of the hard labor required in the transplanting method.

During the 5-year period 1940–1944,[1] the average acreage of sugar beets harvested for seed was 8,490, and the average acre yield of seed was 1,636 pounds.

Culture

Preparing the Seedbed. Since the beet grows largely underground, a deep seedbed is necessary. This fact necessitates plowing and sometimes subsoiling. When practicable, the land should be plowed in the fall so that it may be worked early in the spring. Much care should be taken in the preparation of the seedbed, and it should be thoroughly prepared and made free from weeds before the seeds are sown. Since the best plants are very small and weak when they first come up, poor stands usually results from seeding on rough, poorly prepared soils. If seeds are seeded in weedy seedbeds, much hand weeding must be resorted to, and it is much cheaper to prepare the seedbed thoroughly before seeding.

Planting. Sugar beets are usually planted just after the seeding of spring grain. With machines made for the purpose, the seeds are drilled in rows 14 to 30 inches apart. Experiments indicate that rows spaced 20 inches apart usually give best yields. The seed are planted 1 to 1½ inches deep. Ordinary seed are planted at the rate of 18 to 20 pounds per acre. With segmented seed, 7 pounds are usually sufficient. Single-seed planting of segmented seed allows easier thinning. Though beets

will withstand light frosts, it is usually best to delay seeding until the last killing-frost date is passed.

Fertilization. Sugar beets respond to liberal applications of fertilizers, particularly those elements which are deficient in the soil. Thus we find that from 300 to 600 pounds of a complete fertilizer, such as a 4-16-8, is often used to advantage. The effectiveness of the fertilizer is greater if placed in a single band 1½ to 2 inches below the level of the seed and either directly under or ½ to 1 inch to the side of the row. Small applications of borax are needed on some soils.

Thinning. Each seed ball will produce on the average about two plants, though a seed ball producing four or five plants is not uncommon. For this reason it is obviously impossible to distribute the seed so that an even stand will result. Since it is impossible to seed at the desired rate, the plants must be thinned. Thinning is done by first "blocking" with a hoe; in this process, plants are cut out with a hoe so that small bunches 8 or 10 inches apart remain. After blocking, each bunch is thinned to one plant. This is the most tedious and most particular work connected with beet growing, as improper thinning results in lowered yields.

Mechanized thinning is now receiving more attention and may greatly increase the acreage of sugar beets grown in this country. Mervine and Barmington[3] found that completely mechanized thinning required but 2.45 man-hours labor and produced yields of 12.24 tons per acre; partial mechanical thinning, completed with a long-handled hoe, required 11.6 man-hours and produced 11.4 tons; thinning with the long-handled hoe alone required 15.6 man-hours and produced 11.47 tons; and the usual hand blocking and thinning required 27.2 man-hours and produced 12.17 tons.

Cultivation. A weeder or light harrow may be used for the first one or two cultivations, but afterward frequent shallow cultivations with narrow-toothed cultivators should be given until the tops completely cover the ground. Usually two hand hoeings are necessary in the early growing season in order to keep the crop free from weeds.

Irrigation. In the irrigated sections of the country, beets have the greatest water requirement during the last half of the growing season. A frequent light irrigation of 1 to 2 acre-inches of water will keep the beets growing and in good condition.

Harvesting. The harvesting may be divided into three operations: lifting, pulling, and tipping. Lifting consists in plowing near the beets to loosen the soil so that they may be easily pulled. The pulling is done by hand, and the beets are thrown into piles of convenient size for loading.

Since the part of the beet that grows above the ground is not desired at the sugar factory, as it is low in sugar and high in undesirable minerals,

the top is removed by cutting off at the point of the lowest leaf scar. After the top is removed, the beets are hauled to the factory.

A great deal of work has been done on mechanical harvesting. Many experimental machines have been devised, and much work has been done on them. For many years the problems seemed insurmountable. One by one, the difficulties are being overcome. Four different types of harvesters were made in 1946, and several others were being developed. It is estimated that 1,200 harvesters were manufactured in 1946 (McBirney[4]).

SUGAR CANE (Saccharum officinarum)

Sugar cane is a member of the grass family and is chiefly valued for the juices expressed from its stems. The juice from sugar cane differs from that of sorghum in that the sugar-cane juice, when at the proper stage of maturity, contains sucrose or crystallizable sugar.

Historical. Sugar cane is a native of New Guinea. It is supposed to have been carried to Africa from the East Indies and to have been introduced into southern Europe by the Portuguese, whence it was brought to the West Indies. From the West Indies sugar cane was introduced into Louisiana and Florida about the middle of the eighteenth century. Though the plant was known long before the Christian Era, it does not seem to have been of much importance until after the discovery of America.

Distribution in the United States. The production of sugar from sugar cane in the continental United States is limited to Louisiana and Texas except for small quantities made by plantation mills. During the 10-year period 1934–1943,[1] Louisiana produced an average acreage of 242,200 with an average yield of 18.5 tons per acre. During the same period, 21,700 acres were annually produced in Florida with an average yield of 32 tons per acre. The crop is grown rather extensively for sirup manufacture in Georgia, Louisiana, Alabama, Mississippi, Florida, and Texas (Fig. 73).

Where sugar cane is produced for sugar making, it is usually grown on a very extensive scale, whole plantations often being devoted to the crop. On the other hand, the sugar cane for sirup is produced chiefly in small fields or patches, mainly for home use, with a small surplus for sale.

Description of the Plant. A plant of sugar cane usually consists of a number of stalks growing together in a cluster. This cluster results from the fact that the main stem throws up additional stems from the underground nodes. The plant varies in height but under favorable conditions may reach a height of 15 feet or more. In tropical countries one planting may afford several harvests, the stubble remaining alive from season to season. This fact is true in the Gulf Coast region of the

United States, but in the northern part of the Sugar-cane Belt the plants do not endure the winter, and annual plantings are necessary.

The leaves of sugar cane are somewhat similar to those of corn. The leaf sheath folds around the stem and serves as a protection for the bud or eye, which is borne at the node. The stem is jointed, but the internodes are much shorter than those of corn. Most of the sugar cane grown in the United States is harvested before the inflorescence appears. In tropical countries, as maturity approaches, the plant throws out a dense silky panicle or "arrow" at the top. The small inconspicuous flowers are borne in spikelets, which are surrounded by silky hairs. The percentage of fertile seeds produced in a panicle is very small, and these seeds lose their viability very soon after maturity.

Varieties. The most popular types of sugar cane for sirup production are the purple or red and the striped or ribbon cane. These varieties are also used for sugar manufacture.

Progress in improving sugar cane has been in the direction of increasing yields and developing varieties that can be harvested more easily and economically by machine (Sartoris[5]).

Most of the new C.P., *i.e.*, Canal Point, Florida, varieties are resistant to red rot, root rot, and mosaic. The current varieties of sugar cane in Louisiana and Florida are C.P. 29/320, C.P. 29/120, C.P. 36/105, C.P. 34/79, C.P. 34/120, and C.P. 36/13.

Along with the introduction of new sugar-cane varieties, improved methods of cultivation have been developed, primarily in the time of planting and in mechanization of cultivation and weed control (Arceneaux[6]).

Propagation. Sugar cane is propagated by planting the stripped stalks. At each node these stalks have buds or eyes from which the new plants grow. The "seed stalks" may be planted in the fall where they are to grow, or they may be bedded so as to prevent freezing and planted in the spring. In breeding work, sugar cane is propagated from seeds, but this task is slow and laborious.

Preparation of the Seedbed. The preparation of the seedbed for sugar cane is much the same as that for corn except that it is usually more thorough. When the land is inclined to be wet, it is thrown into beds 5 to 7 feet broad, a water furrow being left between the beds.

Planting. The crop may be planted either in the fall or in the spring. In the northern part of the Sugar-cane Belt, spring planting is most common, and in the southern section the bulk of the crop is planted in the fall. According to Arceneaux,[6] planting sugar cane in the South has been done traditionally in late fall and early spring. Within the past two decades the average planting date has been sharply advanced. Now almost all the planting in Louisiana is done before the old crop is harvested.

Preharvest planting is also practiced in Florida and is being adopted in the sirup-producing states. Old varieties planted in early September often gave poor stands because the young plants were killed by freezing at a stage when sugar reserves were low. But when planting is done in early August, sugar supplies in the seed piece are usually restored before winter. The spacing of the rows varies from 4 to 7 feet according to the locality and the productivity of the soil. As the plants tiller more where conditions are most favorable for growth, the wider spaces are used when such conditions exist. The rows are opened with a plow and the stalks are distributed end to end in the row. A light furrow is then turned from both sides so as to cover the rows and leave the canes covered by 3 to 4 inches of soil.

Cultivation. Mechanization, according to Arceneaux,[6] was greatly stimulated during the war by shortages of labor. Mule-drawn plows and cultivators have been largely replaced by tractor-drawn row plows and cultivators of various types. Weeding by means of hoes and other hand implements has been largely replaced by improved shaving devices, mechanical hoes, and flame cultivators.

Tractor-drawn cultivators equipped with two middle units, each made up of two shovels and a double moldboard, are now commonly used for the first cultivation. Distribution of fertilizer may be combined with this operation by using two distributors attached to the tractor. With this equipment one man can cultivate and fertilize 35 acres a day.

Subsequent cultivation is most efficiently done by means of three-row disk-type tractor-drawn cultivators. Improved units can be operated by two men and will ordinarily cover 80 or more acres a day.

It is possible, under some conditions at least, to control weeds among growing cane, with relatively little injury to the crop, by means of a flame. Thus young, succulent weeds among well-developed cane shoots can be readily killed by flaming, whereas hand-hoeing would be laborious and costly. Heat-treatment is commonly applied by means of a three-row unit, using fuel oil.

Recently tests with 2,4-D, 1 part per 1,000, generally proved superior to flaming for control of susceptible weeds. Sugar-cane plants are not injured by the concentration required for most of the susceptible weeds.

Harvesting. The crop is usually allowed to grow as late as possible in the fall and is not harvested until just before the killing-frost date of the section. The harvesting consists of three operations: stripping the leaves, cutting off the top, and cutting the stalk. The leaves are usually stripped by a hand implement specially devised for the purpose. The tops are cut with a heavy knife, and then the stalks are cut off at the ground with a heavy knife or stout hoe. After the stalks are harvested,

they are loaded on wagons or carts and hauled to the cane mill, where the juice is extracted and made into sugar or sirup.

Yields. The average acre yield of sugar cane in the United States varies from 18.5 tons per acre in Lousiana to 32 tons per acre in Florida. A good average yield of sugar is about 3,000 pounds to the acre. This is accompanied by a yield of molasses of 100 gallons or more. The yield of sirup varies from 250 to 600 gallons to the acre according to the number of tons produced and the kind of mill used in extracting the juice. The total sugar content of cane varies from 12 to 16 per cent.

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Topics for Discussion

1. It has been found that large yields of sugar beets with high sugar content can be produced in the Northeastern states. Why is this not an important sugar-beet section?

2. Why has sugar-cane production decreased in the United States?

SECTION IX

STIMULANTS

CHAPTER XXXVI

TOBACCO (Nicotiana tabacum)

The crops classified as stimulants are tobacco, tea, and coffee. However, of these crops tobacco is by far the most important in the United States and is the only one that will be discussed in this chapter.

Although tobacco is chiefly used as a stimulant, and the acreage is comparatively small, it is one of the great money crops of the United States. In 1939[1] it ranked seventh in value of the crops of the United States but occupied only three-fifths of 1 per cent of the total acreage in crops.

World Production. During the period 1935–1939,[2] the United States produced an average of 1,460,054,000 pounds of tobacco; China, 1,254,539,000 pounds; India, 1,094,013,000 pounds; Union of Soviet Socialist Republics, 557,552,000 pounds; and Brazil, 203,266,000 pounds. These five countries produced approximately 70 per cent of the world's supply.

Production in the United States. The average annual yield for the United States as a whole for the 10-year period 1933–1942[2] was 1,388,967,000 pounds, with an average acre yield of 908 pounds.

Tobacco may be grown in every state in the United States, but certain soil types and climatic conditions are necessary for the highest quality and best flavor in the manufactured product. Tobacco is very sensitive to soil conditions, but these requirements vary with the different types. During the 10-year period, 1933–1942,[2] the leading tobacco-producing states in the United States and their average annual production was as follows: North Carolina, 548,956,000 pounds; Kentucky, 296,818,000; Virginia, 102,505,000 pounds; Tennessee, 102,195,000 pounds; and South Carolina, 90,289,000 pounds. These five states produced a total of 1,140,763,000 pounds or 82 per cent of the entire crop in the United States.

Other important centers of production, especially in certain types, are in Georgia, Pennsylvania, Maryland, Ohio, Wisconsin, Connecticut, and Florida.

Historical. Tobacco is one of the important native American crop plants. It was cultivated by the Indians at the time of the discovery of America. The name "tobacco" is derived from the Indian word *tabaco*, which was the name of a pipe used by the Indians for smoking the leaves of the plant. Tobacco was taken to Europe by the Spaniards at an early date. The botanical name *Nicotiana* and the name of the active principle of the plant, nicotine, are derived from the name of Jean Nicot, a French

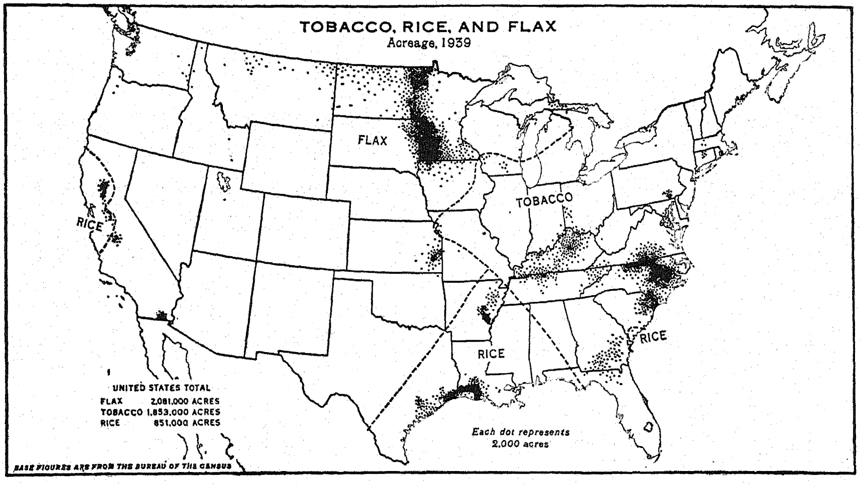

FIG. 74. Tobacco, rice, and flax are grown in localized areas. North Carolina is the leading tobacco state, with 775,000 acres; Kentucky is second with 361,000 acres. In the center of the heavy producing areas tobacco is the principal cash crop. Acreage of rice is confined to the coastal plains of Texas and Louisiana, the lowlands of the Arkansas River, and the adjacent prairie lands of Arkansas, and the Sacramento Valley in California. Rice is the principal food of half the people in the world. Flax is practically all grown in the same area as spring wheat, although some is grown in the valleys of California and in southeastern Kansas. Flax fibers are among the best textile fibers; the oil from the seed is used in industry, and the residue as feed for livestock. (*U.S. Dept. Agr. Bur. Agr. Econ.*)

Ambassador to Portugal, who in about 1560 introduced tobacco into France. Sir Walter Raleigh is usually given credit for having introduced tobacco into England.

The use of tobacco soon became popular in Europe, and it was credited with many virtues, such as allaying hunger, dispelling fatigue, and curing various diseases. The growth of tobacco was closely identified with the development of the early colonies, especially in Virginia and Maryland. It is doubtful whether these colonists could have existed and developed as they did without tobacco, as it was one of the few things produced by the colonist that could be exported and exchanged for many necessary articles that came from the Mother Country. It early became a medium of exchange in the colonies and was used in lieu of money. Whitney and

Floyd[3] state that it was made legal tender in Maryland in 1732 at the rate of 1 penny per pound for all debts, including customhouse dues, and for the salaries of state officers and ministers of the gospel.

According to Garner,[4] commercial tobacco culture began in Virginia in 1612. During the period prior to 1700, exports of tobacco from Virginia increased from 20,000 pounds in 1619 to 500,000 pounds in 1628, 1,300,000 pounds in 1640, and 18,157,000 pounds in 1688. Large quantities were also produced in Maryland during this period, and when Kentucky was settled, tobacco at once became the principal crop in that territory. From Kentucky it was carried into Tennessee and Missouri. It was introduced from Virginia into North Carolina about 1850 and in 1890 became commercially important in South Carolina.

The New England colonists at an early date began the culture of the crop, but tobacco did not become of much commercial importance there until about the middle of the last century, when the value of the tobacco produced in that section for the manufacture of cigars was recognized. From New England the growing of the cigar types was extended into Pennsylvania, New York, Ohio, and Wisconsin. About 1890 the production of cigar tobacco from Cuban and Sumatra seed began to assume importance in Florida and southern Georgia.

Classification. Garner[5] recognizes three general classes of tobacco: (1) cigar tobacco, (2) export tobacco, and (3) manufacturing tobacco. This classification is based on the purposes for which the plant is grown. These classes are further divided into types according to characteristics and appropriate use. In the case of cigar tobacco, there are three principal types corresponding to the three parts of the cigar, namely, wrapper leaf, binder leaf, and filler leaf. The types recognized in manufacturing and export tobacco are Virginia sun-cured, white Burley, flue-cured, and dark fire-cured. The various types are produced on certain special types of soil and according to definite methods of growing, curing, and handling of the crop.

Class, Types, and Groups of Grades. According to Garner,[6] the tobaccos of the United States, including the product of Puerto Rico, are embraced in six classes containing as a whole a total of 26 types, exclusive of the unimportant miscellaneous class, as shown in Table 27. In this system, classes and types of leaf tobacco are identified by arabic numerals, and the groups of grades are distinguished by letters. In the subsequent separation of the groups of grades into individual quality grades these again are indicated by serial numbers, followed by one or more letters to indicate color or other special quality factor. For example, in the leaf grades of flue-cured tobacco, B2L signifies a lemon-colored leaf of No. 2 or fine quality, B4F indicates orange-colored leaf of No. 4 or fair quality,

and X1L refers to lemon-colored lugs of No. 1 or choice quality. This system of classification provides for all types a nondescript grade that is intended to include all leaf that is so mixed or abnormal in properties that it cannot be assigned to any of the regular grades. In all types also there is a scrap grade that is essentially a by-product from handling leaf tobacco and includes floor sweepings and other waste tobacco material except stems.

It will be noted that flue-cured type 11 is subdivided into Old Belt and Middle Belt subtypes. The Piedmont flue-cured area in question is regarded by some as furnishing three somewhat different types of flue-cured leaf, and on this basis type 11 would be split into three types designated as Durham, Winston, and Danville.

In general, the class names do not in themselves give any indication of uses made of the leaf in manufacture except in the case of cigar tobaccos.

The type names in most instances refer to the regions in which the type is produced. The grade names for the most part indicate, either directly or by implication, uses made of the leaf. In this connection it will be noted that cigar-wrapper types produce appreciable quantities of cigar-binder and cigar-filler grades, most of the binder types yield some wrapper-leaf and filler grades, and the binder and filler types also furnish scrap chewing stock in the form of stemming grades. Likewise, cigarette types, such as flue-cured and Burley, also furnish pipe-smoking and chewing grades of leaf. Broadly speaking, local conditions of soil and climate and the variety of seed used, supplemented with appropriate methods of culture and handling, determine the predominant usage of the crop and therefore the type. Production of secondary grades in all types, on the other hand, is due to fundamental differences in properties of the leaves occupying different positions on the stalk. Quality within the grade is influenced by all these factors.

Distribution of Types. *Cigar Types.* The Connecticut Valley area and certain localities in Georgia and Florida are the principal *wrapper-leaf* sections, and Wisconsin, New York, and Pennsylvania produce principally a *binder-leaf* type. The *filler-leaf* type is produced mainly in Lancaster County, Pennsylvania; the Miami Valley, Ohio; and the Onondaga district of New York. There are also restricted areas in Georgia and Florida that produce a desirable filler leaf.

Export and Manufacturing Types. The *flue-cured* type is produced chiefly in southern Virginia, North Carolina, and South Carolina. In recent years this type has been introduced as a substitute for cotton in many of the boll-weevil sections of the other Southern states. The *fire-cured export* type of tobacco is grown almost exclusively in western Kentucky, Tennessee, and central Virginia, and the *Virginia sun-cured*

type is grown in a rather restricted area in north central Virginia. The *white Burley* type is produced in north central Kentucky, southern Ohio, southwestern West Virginia, southwestern Virginia, and southeastern Indiana.

The classification of domestic leaf tobacco is shown in Table 27.

Varieties. There are many varieties and strains of tobacco, and often strains that have the same varietal name are very dissimilar in type. This lack of similarity is due to the fact that only a few tobacco seed plants are required to produce enough seeds to plant several acres, and farmers often differ in their opinion as to what constitutes a good seed plant. Each farmer selects for seed those plants which most nearly meet his ideas of the best type for his conditions, and in a very short time the type may be considerably differentiated. No attempt will be made to discuss the many strains, and only the more important varieties will be mentioned.

An excellent treatise of varieties and strains of tobacco may be found in Chap. 4 of Garner's "Production of Tobacco."[6]

Cigar Varieties. There are three important groups of varieties used in growing cigar tobaccos in the United States. These are (1) the Broadleaf or Seedleaf group, (2) the Havana seed group, and (3) the Cuban group.

Export and Manufacturing Varieties. The principal varieties used in the production of export and manufacturing tobacco may be grouped under these heads, namely, (1) Burley group, (2) Maryland group, and (3) flue-cured and fire-cured.

White Burley is the most important variety in the Burley group. The Maryland is the most important variety of the Maryland group. In the flue-cured and fire-cured export and manufacturing group there are many varieties, most of which have been developed from the Orinoco and Pryor varieties.

Botanical. Tobacco (*Nicotiana tabacum* Linn.) belongs to the order *Solanaceae*, the genus *Nicotiana*, and the species *tabacum*. The plant is a rank-growing annual with a rather small root development as compared with the size of the plant. It has a central taproot from which numerous rather short lateral roots extend. Its roots are in large measure restricted to an area the radius of which is seldom more than 18 inches. It has a simple cylindrical stem that attains a height of from 4 to 8 feet when not topped. The leaves are alternate and often attain a size of 1 foot or more in width and 3 to 4 feet in length. All the green parts of the plant are covered with a soft, downy, glandular pubescence that makes the surface sticky. The stem terminates in a panicle of showy, pink or rose-colored flowers, each with a long corolla tube. The plant is normally self-fertilized, but cross fertilization is easily effected by visits of insects

TABLE 27. U.S. DEPARTMENT OF AGRICULTURE'S CLASSIFICATION OF DOMESTIC LEAF TOBACCO

Class	Type	Grade groups
1. Flue-cured	11. (a) Old Belt (b) Middle Belt 12. Eastern North Carolina 13. South Carolina-North Carolina Border Belt 14. Georgia and Florida	A, wrappers; B, leaf; C, cutters; H, smoking leaf; X, lugs; P, primings; N, nondescript; S, scrap
2. Fire-cured	21. Virginia 22. Kentucky-Tennessee, eastern district 23. Kentucky-Tennessee, western district 24. Henderson or Stemming	A, wrappers; B, heavy leaf; C, thin leaf; T, short leaf; X, lugs; N, nondescript; S, scrap
3. Air-cured: *a.* Light	31. Burley	A, wrappers; B, leaf; C, lugs and cutters; T, tips; X, granulators or flyings; N, nondescript; S, scrap
	32. Southern Maryland	B, heavy leaf (dull); C, thin leaf (crop); X, seconds; T, tips; P, ground leaves; N, nondescript; S, scrap
b. Dark	35. One-sucker 36. Green River 37. Virginia Sun-cured	A, wrappers; B, heavy leaf; C, thin leaf; X, lugs; N, nondescript; S, scrap
4. Cigar Filler	41. Pennsylvania Seedleaf	B, binders or tops; C, fillers; X, stemming grades; Y, ground leaves; N, nondescript; S, scrap
	42. Gebhardt 43. Zimmer 44. Dutch	C, fillers; X, crop-run (C & Y); Y, ground leaves; N, nondescript; S, scrap
	46. Puerto Rican Sun-grown	C, tripas (fillers); X, resagos (inferior); N, nondescript; S, scrap
5. Cigar Binder	51. Connecticut Broadleaf 52. Connecticut Havana Seed 53. New York and Pennsylvania Havana Seed	A, wrappers; B, binders, seconds, and brokes; C, fillers and short darks; X, stemming grades; Y, sandleaf fillers; N, nondescript; S, scrap
	54. Southern Wisconsin 55. Northern Wisconsin	B, binders; C, fillers; X, crop-run (C & Y); Y, sandleaf fillers; N, nondescript; S, scrap
	56. Georgia and Florida Sun-grown	B, binders; C, fillers; X, stemming grades; N, nondescript; S, scrap

carrying pollen from other plants. The seeds are borne in large capsules and are produced in great numbers, a single well-developed plant often producing as many as 1 million seeds.

TABLE 27. U.S. DEPARTMENT OF AGRICULTURE'S CLASSIFICATION OF DOMESTIC LEAF TOBACCO.—(*Continued*)

Class	Type	Grade groups
6. Cigar Wrapper	61. Connecticut Shade-grown 62. Georgia and Florida Shade-grown	A, wrappers; B, stout wrappers or binders; C, fillers (tips); X, filler brokes; N, nondescript; S, scrap
7. Miscellaneous	72. Perique	

Uses. Tobacco is used chiefly for chewing, smoking, and snuff. Low-grade leaf and by-products are used in the production of insecticides, disinfectants, and other nicotine products. The stalks, stems, and some by-products of the nicotine industries are used for fertilizers.

CULTURE

Plant Bed. Tobacco plants are started in beds seeded 6 to 12 weeks before time to set the plants in the field. In the cigar-tobacco sections of the North, the young plants are started in a cold frame or hotbed, but in Kentucky, Virginia, and the states farther south a sunny exposure is chosen, either in recently cleared woodland or in the open field. In bluegrass sections a common practice is to turn a bluegrass sod in the early fall so that the sod will have time to decay by the following spring. The sod is then worked up and raked until a very fine seedbed has been made; the seeds are then sown.

When plant beds are made on recently cleared woodland, the usual practice is to pick a place rich in organic matter and work it up with a mattock or some horse-drawn implement that does not bring any of the subsoil to the top. The bed is then raked until it is in a fine condition.

Sterilization. Since weeds and diseases are very objectionable in plant beds, the beds are usually burned or steamed before the ground is prepared for seeding. When the beds are burned, either wood or brush is piled on them and burned until the soil is thoroughly heated to a depth of 2 or 3 inches.

In the steam treatment, an engine and a metal box are necessary. The box is inverted over a part of the bed with the edges forced well into the soil so that the steam cannot escape. Then the steam is forced into the box until the soil is heated to a temperature of 175°F. to a depth

of 4 inches. The temperature is maintained for about an hour, and the pan is then removed to another area, where the process is repeated. Where suitable steam engines are available, steaming is preferable to burning, as it is more effective in killing both weeds and disease organisms that may be in the soil.

Calcium cyanamide or urea, used singly or in combination, has been effectively used to destroy most weed seeds and some soil-borne diseases on the lighter types of soil. When cyanamide is used alone, it is recommended that 1 pound per square yard of plant-bed area be applied at least 60 to 90 days before seeding. The plant bed should be brought into good physical condition, and three-fourths of the material is then spread evenly over the area and worked into the top 4 inches of soil. After this working, the remainder of the material should be distributed over the surface. Moisture is essential for the destructive action of the cyanamide. It is also essential that this treatment be made well in advance of freezing weather.

Fertilizers. To produce good plants the soil should be very rich in available plant nutrients. It is, therefore, usually advisable to fertilize the beds. Well-rotted farmyard manure applied at the rate of 20 tons to the acre gives good results. Hog manure is splendid for the purpose as it does not carry many weed seeds. However, if the beds are steamed after manuring, any well-rotted manure may be used. Even when the beds have had a good application of farmyard manure, the application of commercial fertilizer is advisable. The fertilizer most commonly used on the plant beds is of the same analysis as that used later on the tobacco fields. This fertilizer is applied at the rate of 50 to 200 pounds to each 100 square yards of plant bed.

Because of injury due to excess of chlorine in plant beds, it is recommended that all potash be derived from high-grade sulfate of potash and/or sulfate of potash-magnesia. The addition of 1 per cent available magnesium oxide will be beneficial in certain cases, and its inclusion is generally recommended. When suitable farmyard manure is not available, very good plants can be grown by the use of commercial fertilizers alone if there is a good supply of organic matter in the soil.

Seeding. The seed is sown on the bed at rates varying from a level teaspoonful to 100 square feet, to the same amount for 300 square feet. Probably the best rate of seeding is an even teaspoonful of dry seed to 100 square feet of bed area. In order to get an even distribution of the seed it is mixed with fertilizer or some other light-colored material, and the bed is gone over several times until the distribution of the filler material indicates that the entire surface has been seeded.

The seed should be raked in very lightly, and the bed then run over

with a light roller. If a roller is not available, the soil may be packed with a short piece of plank with a handle attached.

Care. After the seed has been sown, the bed should be covered with either cheesecloth or glass. In colder sections glass is preferable, but in the South the cheesecloth covering is used almost exclusively.

The beds should be kept moist enough to ensure rapid growth, and weeds should be picked out by hand. When the plants have reached the height of 6 inches, they are ready for setting in the field. The covers should be removed from the beds several days before the plants are to be set in the field, so that they may be toughened by exposure.

Soils and Rotations. According to Garner,[6] the typical *flue-cured* tobacco soils are light-colored sandy loams and fine sandy loams, 6 to 10 inches deep, with yellowish or reddish sandy-clay subsoil. These soils are well drained and have a somewhat limited moisture-holding capacity, and usually their content of organic matter is low. The colloidal content being comparatively low, these soils are inherently low in mineral plant nutrients. A common rotation for flue-cured or bright tobacco is tobacco, small grain, and redtop. These crops afford an effective method of adding a low-nitrogen organic supply to the soil, protect against erosion, and introduce no disease hazard.

Dark air-cured and *fire-cured* tobacco is produced mainly on red or reddish-brown clay loams and gray sandy loams in central Virginia, and on friable silt loams, brown, reddish brown, brownish yellow, or gray in color in western Kentucky and Tennessee. Burley tobacco is grown chiefly on silt loams of limestone origin that contain liberal supplies of plant food elements. Burley thrives especially on the deep, mellow, reddish-brown silt-loam soils of the inner bluegrass region of Kentucky, western Virginia, and the Central Valley of Tennessee. These soils are highly productive, well supplied with organic matter, and easily tilled.

Probably the oldest and most generally used rotation system in the dark air-cured and fire-cured area, as well as the Burley area, consists of following the tobacco crop with wheat, and clover and timothy.

The leading tobacco soils of *southern Maryland* vary from fine sandy loams to silt loams. The plan of growing tobacco continuously on the choicest locations as long as found profitable and then resting these lands for a period of years has had wider application in southern Maryland than in almost any other tobacco-producing region. The period of rest ranges from a decade or more to only 2 or 3 years. A 3-year rotation in which tobacco is followed by wheat, with red clover seeded alone, or with mixed grasses in the fall, has proved satisfactory. It has been found, however, that considerably better results are obtained, especially with

respect to quality of tobacco produced, when the clover and grass following the wheat crop are replaced by 2 years of weeds.

Cigar tobaccos as a whole are grown on an unusually wide variety of soil types, owing chiefly to the fact that soil requirements for production of wrapper, binder, and filler classes of leaf are not the same. They range from the sandy, fine sandy, and very fine sandy loams of Connecticut and Florida to the loams and silt loams of Wisconsin, Pennsylvania, and Ohio.

In the Connecticut *shade-grown-wrapper* area, continuous tobacco culture apparently gives better results than crop rotation. In the Florida-Georgia wrapper area, tobacco is grown each year under the shade until root rot or other diseases become serious, and this is usually a matter of 3 or 4 years. Corn or fall vegetables are then grown, or the land may be allowed to grow up in weeds in preparation for return to tobacco. In the Wisconsin *cigar-binder* districts, the best results are usually obtained with continuous tobacco culture. In Lancaster County, Pennsylvania, a cropping system for the *cigar-filler* tobacco soils consists essentially of a 4-year rotation of tobacco, wheat, clover or alfalfa, and corn. In some instances the corn crop is omitted. In the Miami Valley *cigar-filler* district of Ohio, continuous culture of the crop on the same land is frequently practiced, especially on the smaller farms. The rotation usually followed on the larger farms consists of tobacco, wheat, and red clover or sweet clover, or a mixture of clover and timothy.

Preparing the Field. The land should be plowed either during the winter or early in the spring. Care is required in the preparation of the soil, and it should be in good tilth when the plants are set.

Fertilizer for Tobacco. Special attention must be given to the matter of fertilizing the crop. For all types of tobacco except the flue-cured or bright tobacco, heavy applications of barnyard manure may be plowed into the soil. In the cigar-tobacco districts the commercial fertilizers are commonly broadcast, after the land has been thoroughly prepared. However, in the export- and manufacturing-tobacco sections, after the commercial fertilizers have been drilled in the furrow and thoroughly mixed with the soil, a slight ridge is thrown over the furrow, and the plants are set on this ridge.

Garner[6] states that with most if not all of the principal types of tobacco best results are usually obtained with an uninterrupted, relatively rapid growth rate from the time of transplanting to the approach of maturity, and this requires at all stages an adequate supply of readily available plant food. If too large a proportion is immediately available at the outset, a deficiency may result at later stages of growth because of losses from leaching; on the other hand, an abundance of available plant food toward the end of the growing season may delay or prevent normal

ripening of the crop. The ideal situation is a fully adequate, continuous supply of all essential elements through the growing period but a rapid decline in this supply as the crop approaches maturity.

Rates of Application. The heavier soils of the inner bluegrass region where Burley tobacco is grown require little or no fertilization for the production of tobacco if suitable cropping systems are employed for maintaining a high content of organic matter. As a general rule about 250 to 500 pounds per acre of a 4-8-4 or 3-8-6 fertilizer is used.

In the Connecticut Valley and Quincy, Florida, areas, the rate of fertilizer application averages 2,500 pounds to the acre for the 8-4-8 grade or 2,000 pounds for the 10-5-10 grade. When manure is used at the rate of 10 tons to the acre, the fertilizer application may be reduced by approximately one-half. In the Wisconsin cigar-binder district the common practice has been to apply 15 to 30 tons of manure to the acre and then perhaps supplement the manure with 200 to 400 pounds of a 2-12-6, or a similar grade of fertilizer. In the Pennsylvania cigar-filler district, manure is usually applied at the rate of 10 tons to the acre and supplemented with 500 to 1,000 pounds of a 4-6-10 or 4-8-12 fertilizer.

In southern Maryland, under the more intensive methods of culture, 600 to 1,000 pounds per acre of a 4-8-12 fertilizer is recommended.

The following recommendations for tobacco fertilization as formulated by a committee of the Southern Association of Agronomists, for average soils in Virginia, North Carolina, South Carolina, Georgia, and Florida for the years 1947 and 1948 are here presented:

Recommendations with Reference to the Fertilization of Flue-cured Tobacco Grown on Average Soils in Virginia, North Carolina, South Carolina, Georgia, and Florida for the Years 1947 and 1948*

A. *Analyses of Mixtures and Rates of Application:*

1. *For Heavy or More Productive Soils.* Three per cent total nitrogen, 9 to 10 per cent available phosphoric acid, and 6 to 12 per cent potash, to be applied at rates of 800 to 1,000 pounds per acre.
2. *For Light or Less Productive Soils.* Three per cent total nitrogen, 9 to 10 per cent available phosphoric acid, and 6 to 12 per cent potash, to be applied at the rates of 800 to 1,200 pounds per acre.
3. *Reduction in Nitrogen.* Where tobacco has a tendency to be rough and of poor quality, the nitrogen may be reduced to 2 per cent. For such conditions, 2 per cent total nitrogen, 10 to 12 per cent available phosphoric acid, and 6 to 12 per cent potash is suggested, to be applied at rates of 800 to 1,000 pounds to the acre.

* Prepared and issued by the Agronomy Tobacco Work Conference.

4. *Additional Potash.* Experiments indicate that potash has an important influence on yield and quality in flue-cured tobacco. It is therefore suggested that when less than 50 pounds of K_2O (6 per cent potash in an 800-pound-to-the-acre application) is applied at planting time, or where potash deficiency is anticipated or known, that potash to the extent of 50 to 120 pounds of K_2O (approximately 100 to 250 pounds of sulphate potash equivalent) to the acre be applied as additional side dressings within 20 days after transplanting. High chlorine salts should not be used as side dressers.
5. *Additional Nitrogen.* Where the need of additional nitrogen is indicated, it may be applied, preferably with potash, as a side dresser. The application should not exceed 15 pounds of nitrogen per acre.
6. *Method of Application.* Experiments indicate that fertilizers applied so as to come in direct contact with the plant roots cause loss of plants and retard early growth. It is therefore suggested that fertilizers be placed in bands 3 to 4 inches to the sides of the row at the approximate level or slightly below the root crowns and the plants be set between these bands, or that the fertilizer be *thoroughly* mixed with the soil in the furrow before bedding. Where proper machinery is not available for side placement, it is suggested that 60 per cent of the fertilizer be applied at planting and the remainder as a side dressing approximately 20 days after setting.

Note 1. The foregoing analyses may be modified, provided the approximate ratios are maintained and the recommended sources of plant food are used.

Note 2. Where more than 6 per cent potash is used, farmers are cautioned to apply fertilizer in bands or mix thoroughly with soil to prevent plant injury.

Note 3. These recommendations are based on a population of approximately 5,000 plants per acre. Where plants are spaced closer or extreme high topping is practiced, rates may be increased.

B. *Sources of Plant Food:*

1. *Nitrogen.* One-third of the nitrogen should be derived from high-grade organic materials of plant or animal origin; one-third from materials supplying nitrogen in the nitrate form; and one-third from standard inorganic sources of nitrogen. (Fertilizers that are claimed to be made according to the recommended formulas should contain not less than one-third of the total nitrogen in organic form, and not less than one-fourth of the nitrogen should be water insoluble.) For the purpose of these recommendations, urea is considered the equivalent of an inorganic source of nitrogen.
2. *Phosphoric Acid.* To be derived from any source of available phosphoric acid, provided that the available calcium in the mixture shall conform to the requirements of Subsection 7 of Section *B*.
3. *Potash.* To be derived from any source of available potash, provided the chlorine content of the mixed fertilizers so compounded does not exceed

2 per cent, except that in case of soils where the pH is above 5.6, the maximum may be 3 per cent. Where it is desired to apply additional side dressings of potash, the sulfate is the most suitable form available for the purpose. If tobacco by-products are used as a source of potash, these must be sterilized to kill such disease organisms as might be present.

4. *Magnesia.* It is recommended that fertilizers carry 2 per cent magnesia (MgO), at least one-half of which shall be derived from water-soluble materials, or shall be water soluble in the mixed fertilizer.
5. *Chlorine.* Available experimental data from bright-tobacco sections of Virginia, North Carolina, South Carolina, Georgia, and Florida show that a small quantity of chlorine in the tobacco fertilizer increases the acre value of the crop. Experiments have shown, however, that an excessive amount of chlorine in fertilizers used for tobacco injures its growth and reduces quality, producing a thick, brittle leaf, which when cured becomes thin, soggy, and dull in color. It also has an unfavorable effect upon the burning quality of the cured leaf. It is recommended therefore that fertilizers should be compounded in such proportions that the fertilizer mixtures shall contain 2 per cent chlorine. Where the pH of the soil is above 5.6, the maximum may be 3 per cent.
6. *Sulfur.* Sulfur is essential in bright-tobacco fertilizers but is usually contained in sufficient quantities in the materials recommended for compounding the fertilizers suggested by this conference. Materials containing excessive amounts of soluble sulfate (SO_3) should be avoided in compounding bright-tobacco fertilizers.
7. *Calcium.* Calcium is an essential element in tobacco production, and since fertilizers compounded with high-analysis materials are sometimes low in calcium, it is recommended that tobacco fertilizers carry in an available form a minimum of 6 per cent of calcium oxide (CaO) equivalent.
8. *Boron.* Boron deficiency on tobacco has been observed in a very few instances. The application of not more than ¼ pound of boron per acre (approximately 2.5 pounds borax) is suggested in such conditions, to be applied in the fertilizer at the time of planting or in the side dresser.

C. *Neutral Fertilizers*:

If neutral fertilizers are to be produced, it is suggested that the neutralizing agent be dolomitic limestone, as this material not only neutralizes but carries magnesia (MgO) and calcium (CaO), which are important plant nutrients. Basic fertilizers for bright tobacco are not recommended for general use.

Fertilizers for Plant Beds

Injury due to excess of chlorine has been widely observed in tobacco plant beds. Since fertilizers are applied to plant beds in relatively large quantities, even a small percentage of chlorine in the fertilizers may cause plant-bed injury. It is therefore recommended that only such materials as are practically free of chlorides be used for making plant-bed fertilizers, and that the

fertilizer contain 6 per cent nitrogen, 9 per cent phosphoric acid, and 3 per cent potash applied at the rate of 1 pound to the square yard. The addition of 1 per cent available magnesia (MgO) will be beneficial in certain cases, and its inclusion is generally to be recommended. In compounding this fertilizer, it is recommended that one-fourth of the nitrogen be derived from nitrates, one-fourth from natural organics, and one-half from ony other standard inorganic sources.

Transplanting and Cultivating. Tobacco plants are usually set in rows 3 to 4 feet apart. The distance between the plants in the row varies from 14 to 30 inches for cigar tobaccos and from 16 to 36 inches for the manufacturing and export types.

Tobacco plants of the various types are usually set in the field in the following rates per acre: flue-cured, 5,000 to 6,000; dark fire-cured, 3,600 to 5,000; Burley, 8,300 to 10,800; cigar-wrapper leaf, 10,000 to 13,000, cigar-binder, 6,800 to 11,200; and cigar-filler, 5,400 to 6,200.

The plants may be set out on the level surface of the land, but they are usually set on slight ridges. According to Garner,[6] ridging is the prevailing practice in the culture of flue-cured and to a limited extent is used for dark air- and fire-cured types, and level culture is chiefly used in the production of cigar tobaccos, Burley, and the southern Maryland types. The plants may be set by hand, but transplanting machines are used in some sections. Where hand planting is practiced, the plants should not be transplanted except when there is an abundance of moisture in the soil. The land must therefore be prepared several days ahead of planting time so that the plants may be set as soon after a rain as possible. The best time for setting plants is as soon as possible after the last killing-frost date of the section. Early-planted tobacco cures better than that late planted, although the plants may be set as late as 90 days before the date of the first killing frost in the fall.

Cultivation should begin as soon as the plants start to grow and should be repeated often enough to kill the weeds and to keep the soil loose on top, as long as the size of the plants will permit. The first cultivation may be deep; afterward frequent shallow cultivations are more desirable. It is often advisable to work the soil around the plants with a hoe after the first cultivation, but, if subsequent cultivations are timely and thorough, additional hoeing may not be necessary.

Topping and Suckering. Topping, which means breaking off the top of the plant, is practiced to stimulate development of the leaves. No definite rule can be given for topping, as this depends upon many factors, such as type of tobacco, productivity of the soil, date of planting, and rainfall. In the production of cigar tobaccos, 16 to 20 leaves are often left to each plant; with the export and manufacturing types 8 to 12 leaves

are usually left on the fire-cured type of plant, and 15 to 18 leaves are left on the flue-cured type. The aim in topping is to leave only as many leaves on the plant as can be brought to the fullest development. The suckers or axillary buds come out at the axils of the leaves on all plants that have been topped. These suckers should be removed as often as they appear and should not be allowed to grow more than 4 or 5 inches in length.

Harvesting. There are two general methods of harvesting tobacco: (1) picking the leaves from the stem as they ripen, known as the "priming method" and (2) cutting the stalks with the leaves intact. Both of these methods are used in harvesting cigar and flue-cured tobaccos, but the practice of cutting the stalk is used almost exclusively in the harvesting of dark fire-cured tobacco. After the plants are cut, they are allowed to wilt so that the leaves will not break so easily; afterward the plants are split from the top toward the base and are then placed astride a stick, which is 4 to 4½ feet long, and transported to the curing barns. From five to seven plants are placed on each lath or stick according to the size of the plants.

FIG. 75. Topping tobacco on an Archer, Florida, farm. (*U.S. Dept. Agr. photograph.*)

When the priming method is used, cigar-wrapper leaves are strung with a threaded needle through the midrib of the leaf about one inch from its base. The leaves are strung in pairs, face to face and back to back. The ends of the twine are attached to and suspended from the ends of the lath or stick. About 15 to 20 pairs of leaves are placed on a stick.

Flue-cured tobacco leaves are strung on a stick in groups of three or four leaves per bunch with 25 to 30 bunches being placed on a stick.

Curing. The three common methods of curing tobaccos are (1) air curing, (2) open-fire curing, and (3) flue curing.

In the air-curing process the tobacco is hung on tiers of poles in barns provided with ventilators that admit air freely. In dry weather the ventilators are kept open day and night, but on very damp nights they are closed. In damp weather it may be necessary to keep the ventilators closed day and night. The curing process is slow and may take several weeks if weather is unfavorable. It may also be necessary, in periods of foggy or rainy weather, to use charcoal, or other nonsmoking fires, in the barn in order to keep the inside of the barn warmer than the temperature on the outside.

In the dark-tobacco districts the tobacco is either taken to the barn as soon as it has wilted or hung on scaffolds in the field to yellow to some extent; afterwards it is placed in the barn. After yellowing has gone to the proper point, open fires are built on the ground directly under the tobacco. Slow fires are kept up for the first few days and are then gradually increased until curing is completed. This process often takes 10 days or more. In some cases the fires are not kept up constantly but are built at irregular intervals according to the grower's ideas concerning the need of fire.

Bright tobacco is cured in a much shorter time than either of the other types. The barns have close walls and are provided with ventilators at the top. Furnaces or fire boxes are built in one side and flues lead from these across the house and then back and pass out through the wall a few feet higher than the level at which they left the furnace. The barn is filled with tobacco as quickly as possible. A moderate fire is then started and maintained until the leaf is thoroughly yellowed. The temperature is then gradually raised as the curing progresses, and due attention is given to ventilation so that proper moisture conditions will be maintained. No fixed rule can be given either for regulating the temperature or for adjusting the ventilators, as these operations vary with each curing of tobacco and can be learned only by experience. The temperature is finally raised to 175 or 200°F. and maintained until all the stems are dry. The whole process seldom takes more than 3 days.

Stripping, Sorting, and Tying. After tobacco is cured, it is allowed to hang until the leaves become pliable owing to the absorption of moisture. The tobacco may then be handled without breaking and may be taken down and prepared for market. Tobacco becomes pliable only in damp weather and becomes dry and brittle again when the weather is dry and cool. In order to keep tobacco pliable, it may be placed in bulk and

covered to keep it from drying. Some growers have ordering rooms in which tobacco may be hung and brought into pliable conditions by steam or other methods of supplying moisture to the surrounding air.

Where the entire stalk has been cut and cured the stripping process consists in removing the leaves from the stem. The leaves are then sorted according to quality and tied into "hands" or bundles. A hand is a bunch of several leaves that are tied together at the butts with another leaf. The tobacco is then ready for market and may be sold at the grower's convenience.

SOME INSECT PESTS

Tobacco Flea Beetle. The tobacco flea beetle (*Epitrix parvula*) is a small, oval, reddish-brown insect about $\frac{1}{20}$ inch long. The eggs, which in about 1 month transform into pupae and then into adult beetles, are laid in the soil, and the larvae feed upon the roots of the susceptible plants. The life cycle requires about 1 month, and several generations are produced each season. The adult beetle lives over winter in rubbish that often accumulates in fence corners and elsewhere.

The beetle attacks not only tobacco but eggplants, tomatoes, potatoes, etc. The insects damage the leaves of the tobacco plant by eating small holes in the upper or undersurface or through the leaves. This damage of course affects the selling quality of the crop and in addition makes easier the entrance of certain diseases. The plants are attacked both in plant beds and in the field.

The methods recommended for control are (1) locate the plant beds some distance from tobacco fields, (2) cover the plant beds with cloth and, if the flea beetles appear on the plants, dust the plants frequently with light applications of arsenate of lead when the leaves are dry, (3) destroy weeds in and around the tobacco fields, (4) cut and turn under the tobacco stalks immediately after the crop is harvested, (5) destroy beetles during the winter by burning over hibernation places, and (6) if tobacco is attacked in the field, use frequent light applications of Paris green. DDT, rotenone, and cryolite are also effectively used.

Tobacco Hornworms. The tobacco hornworms *Phlegethontius sexta* (southern) and *P. quinquemaculata* (northern) in the adult forms are moths, one being more common in the North and the other in the South. The southern is darker, with brighter orange spots on the abdomen, while on the wings the white lines are less distinct.

The pupae overwinter several inches below the surface of the ground, and the adult moths emerge in May and June. On the undersurface of the leaves the females deposit eggs from which the larvae emerge in from 4 to 8 days. The larvae, which are very ravenous and devour

leaves in large quantities, become full grown in about 3 weeks after molting four times. They are 3 to 4 inches long and dark green in color with white stripes on the side of the body. The stripes of the northern species are V-shaped and those of the southern species are single, oblique bands. A short horn is attached to the tip of the abdomen; in the northern species the horn is black, and in the southern species it is red. From the presence of the horn the insect is sometimes called "hornworm." The larvae enter the ground and pupate for about 3 weeks, when the adults emerge, the entire life cycle requiring about 6 to 8 weeks. In the South two generations occur each season, but in the North only one is produced.

Control. The insect is often controlled by picking off the larvae as they appear. Flocks of turkeys and guineas have been widely used as a means of control, as they pick the worms from the leaves without injury to the plants. The plants may be dusted or sprayed with arsenate of lead or Paris green, although there are objections to both. One part of Paris green, diluted with six parts of hydrated lime, and used as a dust at the rate of 7 or 8 pounds per acre has become a substitute. Also, cryolite, diluted with clay, talc, or flour, has been used effectively as a dust or spray.

Tobacco Budworm. The eggs from which the budworms hatch are laid by a greenish-colored moth on the upper leaves of the tobacco plants. After hatching, the young worms migrate to the buds, where they remain and feed on the young leaves. Budworms usually begin to appear on the plants within 10 days or 2 weeks after the plants are set in the fields, and, from this time until the end of the growing season, eggs and larvae are present in the fields.

The best method reported for controlling the tobacco budworm is to apply to the buds a mixture of corn meal (75 pounds) and arsenate of lead (1 pound). A very small portion of this mixture is dropped into the center of the bud once or twice a week until the plants have been topped. Two applications a week are necessary for cigar-wrapper tobacco and one application a week is sufficient for bright or flue-cured tobacco.

SOME DISEASES

There are many diseases of tobacco, and the losses from these diseases result in an average of about 15 per cent of the total market value of the crop. Various diseases affect the root, stem, and leaves of the tobacco plant. Affecting the tobacco root may be found such diseases as black root rot, brown root rot, root knot, and meadow nematode. The tobacco stem may be affected by such diseases as damping-off, sore shin, stem rot, hollow stalk, black shank, and Granville wilt. The tobacco leaf is

subject to such diseases as blue mold, wildfire, angular leaf spot, frogeye, mosica, ringspot, and Frenching. Only a few of the more important diseases will be discussed because of lack of space. Detailed information on all diseases may be secured from Chap. 13 of "Production of Tobacco" by Garner.[6]

Root Rot. Root rot is of considerable importance because of the serious losses that sometimes ensue from the attacks of this disease.

The root rot disease is caused by the fungus *Thielaviopsis basicola*, in connection with other organisms such as meadow nematode.

The disease may first be noticed in plant beds. The diseased plants are small and stunted, whereas the healthy ones are vigorous and strong. The roots of the affected plants are small in size and few in number. They are also in the process of decay, which begins at the tips. The plants frequently have a sickly yellow color and may not reach sufficient size to transplant. Often the plants are set in the field, and new roots form. If the season is cool (60 to 75°F.), the plants will remain for 2 or 3 weeks without any apparent growth, and they will become yellow and die. In warm seasons (80 to 100°F.) the diseased plants may partially or wholly revive. The characteristic symptom of the disease in the field is a dwarfing of the plants resulting from decay of the root system.

The fungus lives from year to year in the soil where it can maintain itself, subsisting on decaying plant matter. Land badly infested is said to be "tobacco sick," a condition that is commonly believed to be due to depletion of available plant nutrients. In addition to tobacco, the fungus attacks other plants such as peanuts, soybeans, bur clover, cowpeas, lespedeza, sweet clover, crimson clover, and red clover.

Control. The losses from the disease may be greatly reduced by rotation of crops, by keeping the pH of the soil below 5.5, by seedbed disinfection, and by the use of disease-resistant strains of tobacco. Considerable progress has been made in the development of strains of white Burley tobacco resistant to root rot.

Also, in the flue-cured areas, new varieties such as Yellow special, 400, and 402 have been recently developed.

Mosaic. The mosaic disease of tobacco is caused by an ultramicroscopic organism or virus. The new leaves of diseased plants, whether in the top or in the suckers, are mottled. The dark areas usually consist of nearly healthy tissue, whereas the lighter areas may be various shades of green or yellow. In more severe cases, the dark areas, instead of being smooth, are often raised into quite large blisters, giving the leaf a very distorted shape. The plants are stunted, and the older leaves, although more uniform in color than the younger ones, remain distorted and stunted and often develop small dead spots that may spread and unite,

leaving large burned areas on the leaf. The disease is spread very readily, especially on hands of workers. After the fingers become contaminated by handling a diseased plant, rubbing a healthy plant sufficiently hard to break the hairs on the surface of the leaf will infect it. The disease, therefore, if present in a few plants in the field, will usually be spread to many others during topping and suckering, and also perhaps during worming.

Recommendations for the control of tobacco mosaic include thorough burning or steaming of the bed, keeping tobacco trash from the bed, elimination of unsterilized chewing tobacco while handling plants, the destruction of any mosaic plants that develop in the field, or if this is not done, making it a point never to handle a mosaic plant if healthy ones are to be handled afterward.

Mosaic-resistant varieties are now being released by experiment stations.

Downy Mildew. This disease is commonly called "blue mold." It is caused by the fungus *Peronospora tabacinal.* The disease was first observed in the United States in 1921, but not again until 1931. It is primarily a seedbed disease, though occasionally it attacks plants in the field. The first indication of the disease in a bed is the appearance on a few leaves of indefinite yellow blotches. On the undersurface of these spots is a cottony fungous growth that is either white or pale violet in color. On the upper surface of the spots numerous brown flecklike lesions soon appear, and in a few days these enlarge and run together, forming irregular dead areas. Small plants may lose most of their leaves and still have strength to make new foliage if aided by favorable weather conditions. Transplanting from diseased beds before recovery has begun often results in the death of large numbers of the plants set.

Blue mold may be controlled by dusting or spraying the plants in the plant bed, before the disease appears, with fermate. This material should be applied to the plants about twice each week from the time the plants are the size of a dime until they are set in the field. Rainy weather will necessitate more applications.

Granville wilt. According to Garris and Ellis,[7] Granville wilt is a root and stem disease caused by a bacterial organism that is able to live on dead remains of plants in the soil as well as on many living plants. This disease was first observed in Granville County, North Carolina, about 1900.

The first sympton of Granville wilt to appear on an infected plant is wilting of one or more leaves, usually near the top of the plant. This is followed by wilting of additional leaves, beginning with those adjacent to the first one showing symptoms, and usually continues until the entire plant is affected. Dark areas are to be found in the woody tissues of

infected plants extending from dead roots up the stem and usually connecting with wilted leaves. In the early stages of wilt, one or more diseased roots can be found on infected plants.

Methods of control of Granville wilt are crop rotation and sanitation. The rotation should be 4 or 5 years in length and should not contain susceptible crops such as peanuts, eggplants, peppers, potatoes, and tomatoes. Along with rotation it is extremely important to carry out certain sanitary practices designed primarily to (1) prevent recontamination of fields under rotation with the wilt parasite, (2) prevent spread of the parasites to uncontaminated areas on the same farm, and (3) prevent spread to adjacent and distant farms.

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Topics for Discussion

1. There is perhaps at least ten times as much land in the United States adapted to the production of tobacco from a soil and climatic standpoint than is now used for that purpose. Is it desirable rapidly to expand its production?

2. Why are lands low in nitrogen and lime best for cigarette types of tobacco?

3. Is tobacco valuable only as a luxury and a stimulant?

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